THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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VOL. CXLI.—Nos. 841-846.

JANUARY-JUNE, 1896.

PHILADELPHIA:

Published by the Institute, at the Hall, 15 South Seventh Street.

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Vol. CXLI.—January-June, 1896.

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JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLI. JANUARY, 1896. NO. 1

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE FRANKLIN INSTITUTE.

Stated Meeting, November 20, 1895.

MR. JOS. M. WILSON, President, in the Chair.

A NEW SYSTEM OF MACHINE TELEGRAPHY.

BY PATRICK B. DELANY.

In telegraphy, as in nearly all other industries, there are two ways of working: by hand, and by machine. Naturally the hand method comes first. It was so in telegraphy, and it has continued with wonderful tenacity. Even now, probably 90 per cent. of the telegraph business of the world is done by hand. In America and England, it is by hand and sound. In all other countries, by hand and sight, although Belgium is just beginning to use the sounder. France, Germany, Italy, Austria, Spain, Russia, and, in fact, the rest of the world, use the Morse key, and a receiving instrument which records the dots and dashes in ink on a paper

tape. There are, however, a number of through circuits operated by the Hughes system. Transmission is by keyboard, and the message is received printed on a tape, similar to the tape-printing system of Phelps, which is used in a small way in this country.

England may be said to be the only country using machinery, to any considerable extent for the operation of its telegraphs. It employs the Wheatstone system. This is of English origin. Its inventor was knighted for it, and deservedly so, for it is a great system. In its operation, messages are first punched on a tape, which, in effect, becomes a stencil, taking the place of the operator's hand manipulation. This punched strip is passed through a transmitting machine run by weight and clockwork, and, as impulses are sent wherever there is a hole in the paper, the dots and dashes go into the line with perfect uniformity and at great speed.

The receiving instrument records these dots and dashes in ink, on a tape, as in the case of hand transmission.

This receiver, however, will record ten times faster than the fastest operator can send by hand, hence the advantage of machine transmission. And again, a machine can be made which will transmit ten times faster than the ink recorder will receive, hence the necessity for a quicker recorder than the inking machine. The Wheatstone receiver comprises clockwork, which pulls the paper tape at a rapid rate; and an electro-magnet, the armature lever of which, at its point, alternates between an ink well and the moving tape, making dots and dashes in response to the impulses coming over the line. The rapidity with which a current coming over a long circuit can be made to move this ink-marking lever determines the speed of the Wheatstone system.

It is claimed that, experimentally, 600 words per minute have been recorded. This would require the armature lever to touch and mark the moving tape 200 times per second.

The practical speed of the system over an ordinary circuit is about 200 words per minute. Apparently, the limit of rapidity of electro-mechanical movement at a distance has

been reached, notwithstanding that the impeding effect of self-induction in the electro-magnet itself has been almost completely overcome by the use of the condenser shunt, for there is still the inertia of the moving armature and retardation of the line to be taken into account.

For higher speed at the receiving end of a line, *electrolysis* seems to be the only recourse. It is at least ten times quicker than the fastest electro-magnet, which is to be found in the latest Wheatstone receiver.

Alexander Bain was the first to introduce chemical telegraphy. He turned to account Humphrey Davy's discovery that by electricity a record could be made on paper saturated with certain chemicals.

Now, while Bain's idea was greatly in advance of the necessities of the time, his apparatus was not equal even to the very limited requirements of forty years ago.

The Wheatstone system, with influence and ability behind it, occupied the field and was improved from time to time, to keep pace with the increasing demands for higher speeds, until five or six years ago, when the limit was reached; nor is it likely that this system can ever be made to do any more than it is now doing.

The chemical system has been beset by many drawbacks. It never had a practical perforating machine. The transmitting instrument was very defective, and in Bain's time the way of overcoming "tailing"—or the running together of the dots and dashes on the receiving tape—caused by retardation of the line, had not been discovered. Consequently, chemical telegraphy in the early days, and even up to about 1870, was a very slow system indeed. It was very unpromising until the discovery, I think, by one of the Varleys, that an electro-magnetic shunt around a chemical receiver, would, by its opposing current of self-induction, clear out the tailing or shading between signal marks on the chemically saturated tape. Previous to this discovery, when anything like high speeds were attempted, the dots and dashes appeared as a continuous line.

This self-induction, however, has its drawbacks, for the reason that in order to generate it, a large portion—certainly

one-half of the signaling current—must be diverted from the recorder. Furthermore, while it improves the definition, this self-induced current has a tendency to clip or shorten the primary impulses, and, unless properly balanced, will appear as a reversal or negative record between the regular signals on the receiving tape. For these reasons it is best to get along with as little of the self-induction remedy as possible, consistent with legibility of signals.

If electrolysis could be brought about as quickly with small pressure as with greater electromotive force, the speed of transmission could be increased proportionately. The higher the force sent into the line, the longer it takes to disappear from the receiving tape. This would suggest the advantage of more sensitive chemical combinations for the paper, but then they might be affected by stray or induced currents from neighboring wires. The present formulæ seem to ignore all but the legitimate impulses coming over the line.

The susceptibility of the receiving tape depends on the speed at which it is running. If the movement is very slow, a very weak impulse will make a distinct mark. If the tape is running fast this plain mark will be drawn out, and will be very faint. It is a question of time and current. High speeds require fast-running tape, and the quickly passing chemicals require correspondingly higher electromotive force for dissociation or separation, so that the iron wire may be attacked and corroded, thus causing the mark on the tape. Shortness of application must be made up by increase of pressure.

Another very serious obstacle in the way of chemical, and, in fact, all machine or rapid systems, has been due to the current which discharges towards the sending end of the line after each signal impulse has been sent in. These outcoming currents are proportioned to the charge that creates them. When a dot is sent, the line is not fully charged, not as much so as when a dash is sent; therefore, the discharge after a dash is much greater than the discharge after a dot. It follows that the discharge from a dash, opposing the passage of a dot, hinders and neutral-

ises it to a very detrimental degree. The simplest remedy for this trouble is to send no dashes into the line, making all signals of exactly the same duration, and thereby secure uniformity of discharge current as well.

The remaining important defect in machine telegraphy heretofore, was in the transmitter.

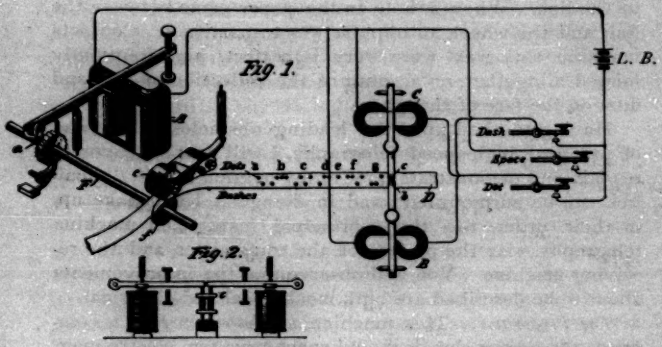
With the exception of the Wheatstone transmitter, which is entirely too slow for chemical telegraphy, all mechanical transmitters used or proposed have consisted of a revolving wheel over which the perforated tape was drawn. This wheel was connected to the transmitting battery. On top of the tape pressed a scraping finger, which was connected to the line. When a hole in the paper came between the line and the wheel, an impulse was transmitted. Contacts made in this way were very imperfect, and frequently missed altogether, on account of the collection of dirt and dust on the face of the wheel.

Having touched upon the leading obstacles in the way of practical high-speed telegraphy, I will now endeavor to explain and demonstrate how, in my opinion, these difficulties can be surmounted; and in doing so, I will take up, in their order, the three principal features of machine telegraphy, viz.: the perforator, the transmitter, and the receiving machine. You will observe that the improvements about to be described are both mechanical and electrical.

The Perforator.—This machine, as shown in *Fig. 1*, comprises three keys, dot, dash and space key; two electro-magnets for forcing the punches through the tape, and a step-by-step tape-feeding device, also controlled by an electro-magnet.

The operation is as follows: The ribbon is perforated in two lines, the holes in the top line representing dots; those in the lower line dashes. The letters are made of combinations of dots and dashes, preferably according to the Continental Code. The lower contacts of the three keys are connected to one pole of the battery, *L B*. The dot-key lever is connected to the punch magnet, *C;* the dash lever to punch magnet, *B;* and the space lever to space magnet, *A*. Obviously, but one key is pressed down at a

time. The spacing magnet is in series with the dot and the dash magnets. To punch the letter *A*, the dot key is pressed down, magnet *C* forces its punch through the paper, and, at the same time, the lever of the space magnet is drawn down, and pawl *a* takes a new tooth in the ratchet wheel on shaft *F*. When the key is released and the circuit broken, the punch is raised out of the die and the strip is drawn a definite length by the sawtooth wheel *f*, and pressure wheel *e*. Then the dash key is operated in the same way, after which the space key is touched, which provides a space between the letter punched and the one which is to follow. Thus,



the space key is pressed down once after each letter, and three times after each word.

Perforating is no more laborious than working an ordinary Morse key, and the speed, with a little practice, will be fully up to the average of Morse transmission.

A side view of the punch magnets, their levers and punches, is shown in *Fig. 2*.

The Transmitter.—The transmitter, as shown in *Fig. 3*, consists of a paper-pulling device, represented by roller *R*, and the two pairs of wire brushes pressing toward each other above and below the tape. The top brushes are electrically one, and are connected to the line *L*. The bottom

brushes are insulated from each other, one being connected to the positive, the other to the negative pole of the main transmitting battery, *MB*. This battery is connected to earth at its middle.

The paper tape separates the brushes, when a hole in the top line is drawn between the brushes, a positive impulse, representing a dot, is sent into the line. When a hole in the lower line is drawn between the other brushes, a negative current, representing a dash, is sent.

In this manner all the dots and dashes on the tape are transmitted.

The brushes are made up of six wires each, so that six contacting points come together at each perforation, ren-

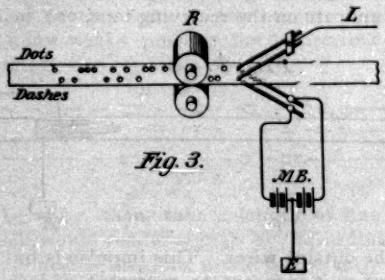


Fig. 3.

dering failure impossible and insuring perfect uniformity in the quality of the impulses. The ends of the brushes are kept bright and clean by the edges of the holes, and a pressure may be put on them which will insure electrical contact with the tape moving 30 feet per second, or at the rate of 8,000 words per minute, or over 2,500 impulses per second.

In this form of transmitter there are no movable or adjustable parts, no circuit wheels to get dirty, no loose or lubricated contacts. An electric motor is used to pull the perforated tape.

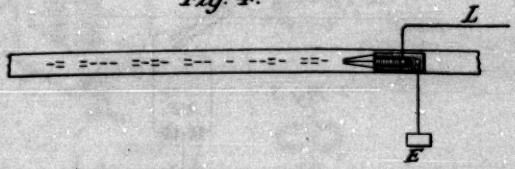
It will be seen that as no dashes are sent, but only dots, which, owing to their position on the tape, *represent* dashes, the impulses are of uniform duration, and the line is not

more heavily charged at one time than another; and consequently, the discharge is also uniform, and the signals on the receiving tape are correspondingly regular.

The Chemical Receiver.—The receiver is shown in *Fig. 4.* It comprises a wheel over which the chemically moistened tape is drawn under three thin iron wires which press lightly on top. The two outside wires are electrically one, and are connected to earth. The middle wire is insulated from the others, and is connected to line.

When the brushes of the transmitter drop into a hole in the dot line, a positive current is sent, and a dot is marked in the track of the middle wire of the receiver. When the transmitter brushes drop into a hole in the lower or dash line of perforations, a negative current is sent, and a dot is marked in duplicate on the receiving tape, one in the track

Fig. 4.



of each of the outside wires. This impulse is but a dot in duration; but as it is meant to represent a dash, it must have something to distinguish it from the dot signal; therefore, the current is forked or divided on the receiving tape, so that all dashes are in the form of double dots, while the dots proper are single, and occupy the centre line on the tape. It will be understood that the chemically moistened tape forms the circuit between the center wire and the outer wires of the receiver, or between the line and earth; and that all positive currents come over the line and mark in the track of the middle wire, while negative currents come from the earth, and mark in the track of the forked contact, forming double dots, which are recognised as dashes.

In this way, no matter how bad the "tailing" may be, it is impossible to mistake a dot for a dash, or to connect them

together erroneously; neither is it necessary to have definition between successive dots or dashes. The length of the composite, single or double mark, determines at once the number of distinctive marks intended. In cable signaling, there is practically no definition as to the number of impulses in the undulations of the ink line. The proportion determines. Of course, in this system of perfectly straight marks in distinctly different lines, translation is much easier.*

The specimens of record, *A* and *B*, seen in *Fig. 5*, illustrate this most important feature. *B* shows the word "telegraphy" with clearly defined individuality of each dot and dash. *A* shows the same word without any definition whatever, but, notwithstanding, the word to a practised eye is just as plain in this form as the other. It is safe to say that, with a few weeks' practice, the transcriber would not look for definition in signals.

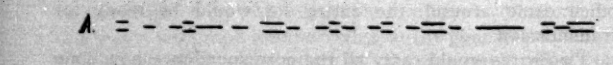


FIG. 5.

It will be clear, then, that a length of line, or rate of speed, which would render signals by the ordinary dot-and-dash method utterly illegible, would be perfectly practicable with this method.

Having dealt at considerable length with the technical side of the subject, I must be brief in referring to the commercial possibilities of machine telegraphy.

A perforator will prepare messages as fast as a Morse operator will transmit by hand. The machine transmitter will send, between New York and Philadelphia, over a common iron wire, at least 1,000 words a minute, or as much as can be sent over 50 wires by hand, simplex. If quadruplex

*[At this point, Mr. Delaney made several experimental transmissions through an artificial line of 800 ohms resistance, and 2 microfarads capacity, or the equivalent of an ordinary iron telegraph wire between New York and Philadelphia. Perfectly legible records were obtained at a speed of 1,200, 1,800, and finally 2,400 words per minute, as timed by Mr. Thomas Shaw, M.E., and others.—The Secretary.]

is used, 15 wires will be required to compete with the machine system on one wire. With a copper wire of 500 pounds to the mile, the machine system will carry 2,000 words per minute, or as much as 30 wires worked quadruplex.

The general introduction of this system for carrying correspondence would require but one or two wires between large cities, and a way wire for smaller places. Any number of towns up to the capacity of the wire could be communicated with in rotation, and messages exchanged. Beginning at one end of the line, each station would clear out with all the other stations, and would send to the main distributing and collecting office on the circuit, messages for points not on the wire. In this way each office would have what would practically be a half-hourly electrical mail service. Telegraph letters would be perforated as fast as they were handed into the office; so that when the time of each office came around, the entire lot would be ready for transmission.

Two wires would carry all the correspondence now done between New York and Philadelphia; one would accommodate New York, Baltimore and Washington; New York and Boston would require one wire, and one would suffice for way stations. Two through wires would be necessary for New York and Chicago, and so on.

This plan, carried out so as to cover the country, would speedily supplant the present mail service for all correspondence of any urgency, and would take from the present telegraph and telephone companies a great portion of their business, not of sufficient urgency to warrant the comparatively very high charges, when a service equally as good is available at one-tenth of the cost.

Business houses having a large correspondence, and newspapers, would take advantage of the very low rate for simple transmission of dispatches handed in already perforated, and to be delivered on the received strip without translation. Such service would probably not cost more than 5 cents for 100 words between New York and Philadelphia, exclusive of delivery charges, or 10 cents between New York and

Chicago. For regular patrons, carrying on extensive correspondence, special arrangements could be made for delivery, or the parties themselves could send to the telegraph office at stated times, and receive their dispatches from their box, after the plan of the present post-office system. These means, with the regular post-office delivery, would be the most satisfactory and least expensive for this service, the object being simply to substitute the wire for the railway train for conveying correspondence from one point to another, leaving the collection and delivery to the present very efficient and reliable post-office service. In no other way could very low rates be maintained. There would be no branch offices.

Messages would be sent or mailed to the central station, located close to the general post-office, in each city. Everything addressed to the central station of the company would be dropped in a special drawer, which would be constantly emptied by the telegraph company's collector. In this way a telegraph letter arriving at the general post-office would immediately be taken to the telegraph office, perforated, and transmitted to its destination, where it would be dropped in the post-office for delivery, thus practically eliminating the time now consumed in the railway journey.

DISCUSSION.

MR. THOS. SHAW:—Do you derive any advantage from the use of reverse currents?

MR. DELANY:—Only so far as they admit of placing the dots and dashes in separate lines on the receiving strip. If the reversals were regularly alternating, of course, there would be a gain in clearing the line; but they are not, since all the dots are sent from one potential, and all dashes from the other. Therefore, several impulses of the same polarity, varying in number from one to four, follow each other; but, as already pointed out, the composite character of these marks at great speeds does not in any way interfere with translation of signals; the dashes being in double and the

dots in single lines, cannot be merged, as the length—in the absence of definition—determines clearly the number of dots or dashes in the marks. A glance at the strip is sufficient to realise the difference between one, two, three or four dots or dashes, the means of verification by comparison being always before the transcriber. It is well known that in cable telegraphy—the most accurate of all signaling, indeed, marvellously so, when the unmeaning and unpronounceable code words are considered—there is, as already stated, little or no definition, the number of dots or dashes being known by the dimension of the curve in the undulating lines made by the siphon recorder. In my system, definition never entirely ceases; but were dots and dashes all in the same line, as heretofore, translation would be rendered unsafe before half the present speed could be reached.

MR. E. A. SCOTT:—Has this system ever been tried on a regular line?

MR. DELANY:—Yes. On the 13th of October, in this city, a trial was made over a wire to Harrisburg and return, 216 miles, principally of No. 11 copper wire, 130 pounds per mile, and about 25 miles of ordinary iron wire. The speed reached was 940 words per minute, perfect record. I have some of it here. The weather on that occasion was very stormy and the leakage of current very great.

So far as resistance is concerned, this circuit was about twice as long as a line of 850 pounds per mile of copper would be from New York to Chicago, but the electrostatic capacity was very much less. The electromotive force used was 120 volts, or about one-half the pressure used for quadruplex (Morse) working.

(ABSTRACT.)

METALLURGICAL AND OTHER FEATURES OF JAPANESE SWORDS.*

By Benjamin Smith Lyman.

The lecturer was introduced by Mr. F. Lynwood Garrison, Professor of Economic Geology and Metallurgy in the Institute.

JAPANESE SWORDS.

Forging.—The smith carefully selected and tested his steel or iron; for, although the earliest swords were made of copper or bronze, only steel and iron have been used for many hundred years past. Preferably steel alone was used, but sometimes one-third, one-half, two-thirds, or even more iron was intimately united with the steel by welding bars together. The metal was generally Japanese, but in the last 300 years European metal has occasionally been used, and then sometimes marked as metal of the "Southern Barbarians."

In the all-steel or "pure-make" style of forging, as distinguished from the "mixed-make," several flat pieces of steel amounting all together to something over a quarter of the weight of the sword, are placed one on another, with an iron rod welded as a handle to the lowest one, and are heated in the fire. To prevent the conversion of the steel into soft iron by "burning," or oxidising its carbon, and also to keep the surface of the metal free from iron oxide that would be injurious if hammered in, the steel is never heated without being previously covered carefully with a thin wash of refractory loam and sprinkled with straw ashes, an ingenious precaution that is unknown in Western countries

* Abstract of a lecture delivered before the Franklin Institute, Friday, November 8, 1895.

The metal, too, must be kept scrupulously clean and never touched with the hand, as the least sweat will hinder perfect welding and leave a flaw visible in the sword.

The little pile of steel plates is hammered on the anvil into a single flat bar, 6 or 8 inches long, by a couple of inches wide, and perhaps ½ inch thick. The bar is then doubled over, end to end, heated again and hammered out to a bar of about the same size as before; then doubled again, reheated and hammered out once more; and so on, until it has been folded and hammered out fifteen times. Then the iron handle is cut off. In that way three more such bars are made. The four bars are then welded upon one another into a somewhat larger, thicker bar, and this again is five times doubled over and hammered out to about the same dimensions. The object of all this folding and hammering out is, of course, to secure perfect homogeneity with a thoroughly fibrous structure.

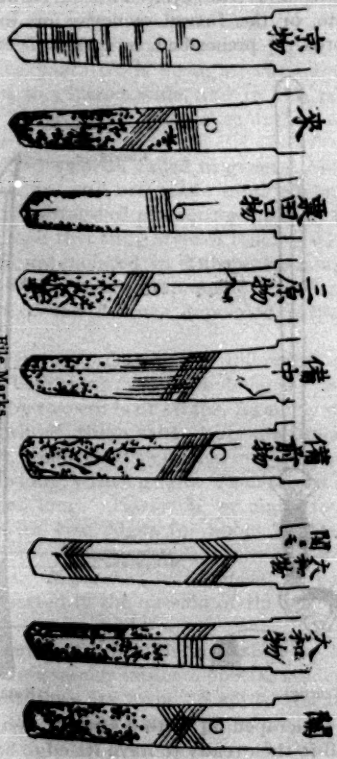
It is readily seen that an immense number of layers has been produced thereby. The first doubling gives 2, the second 4, and so on, 8, 16, 32, 64, 128 (or more than 125), over 250, 500, 1,000, 2,000, 4,000, 8,000, 16,000, and the fifteenth over 32,000 layers. The four small bars together would have then over 125,000, and the five other foldings would give over 250,000, 500,000, 1,000,000, 2,000,000, and finally over 4,000,000 layers.

The polished sword has consequently fine lines like the grain of wood, and they are called the sword's hide or skin; and are distinguished by names according to the form, such as: straight-grain-skin, board-grain-skin, pear-skin, like a halved pear, pine-skin, ragged like pine bark.

When iron is used along with the steel, there are several ways of combining the small bars to make the larger one; for example: a steel bar between two iron ones; an iron bar welded on a steel one, and folded over lengthwise with the steel inside; a bar of iron and one of steel welded together along the edge, and covered by an iron bar as wide as both together, and then the whole folded lengthwise so as to bring the steel along the middle of one edge; and eight or ten or more ways, down to simply applying an edge of

steel to a back of iron, a very inferior method, but quickly done and common in war times.

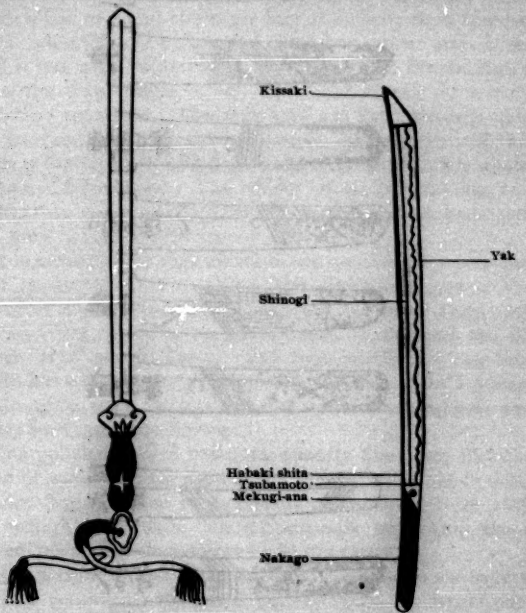
The resulting bar of steel, or steel and iron, is then, with



File Marks.

frequent and partial heating, hammered out to the length of the desired blade, somewhat curved according to the final shape; and both ends are cut off, where the metal is

inferior. The point is formed, and, by hammering thinner towards the edge the right breadth is given, and the blade gets its rough shape, not by any pattern, but by the smith's practiced skill and true eye. The curve depends on the smith's taste, or the future owner's; or, in certain ceremonial swords, is prescribed by rules of etiquette. The



Tsurugi. Katana.

rough blade is scraped off with a kind of metal draw-knife, and filed, and is then ready to have its edge hardened, or to be tempered.

The shape of the file and the direction of the lines it makes have, of course, nothing to do with the quality of the sword, but as the lines remain permanently on the tang,

under the hilt, they serve in some degree for the identification of the sword-maker, and special names have been given to different arrangements of them.

The shapes and sizes of swords are various, and give rise to many names and ways of classifying.

The *tsurugi* is the primeval sword of Japan, not used for many centuries past. It is straight, two-edged, 28 to 40 inches long, 2½ to 3 inches wide, and in the middle ⅜ inch thick, with a short point, and is more for cutting than thrusting.

The one-edged swords, called in general *katana*, are also mainly for cutting, and are made more effective by being curved. The advantage of protecting the body by the sword kept before it, in a thrusting style of fencing with a straight, pointed sword, appreciated in Europe from ancient times, seems never to have been comprehended in Japan and Asia generally, where the defence depended rather on heavy armor.

The one-edged swords are the following, according to their length, beginning with the longest: *tachi*, strongly curved, hung by two cords or straps, formerly worn by generals as a mark of their rank, but now somewhat rare. *Katana* proper, some 30 to 33 inches long. *Wakizashi*, some 18 to 20 inches long, with a guard. *Tantô* (short sword), some 11 or 12 inches long. *Yoroi-tôshi*, or mail piercer, about 7 inches long, with two edges for about half-way from the point. *Kuwai-ken* (bosom sword), about 6 or 7 inches long, worn by ladies. *Kogatana* (little *katana*), or paper-cutter, a small knife inserted in the outside of the scabbard of many short swords.

Several other forms are distinguished by less common names; and some names indicate special modes of wearing a sword rather than its form. Swords are also classified according to the shape of their main cross-section, to the form of the back, to the grooves cut in the blade, and to the general curve of the blade.

Tempering.—In the tempering, the Japanese process is again peculiar, and particularly ingenious and advantageous. We must remember that steel, when heated red-hot

and suddenly cooled, becomes hard, brittle and elastic, to a greater or less extent, according, not merely to its composition, but to the degree of the heat and the suddenness and degree of the cooling. When this hardened steel is heated again and allowed to cool slowly, it becomes soft and malleable once more, in a degree proportioned to the heat just given, and that is called "softening" or "annealing" the steel. Tempering steel implements generally means a combination of first hardening, and then, by annealing, reducing the hardness to the desired temper; that is, to the amount of hardness that best fits the implements, each according to its use, for resisting wear and tear, with the least possible brittleness, at the same time. Commonly, with us, a sword is hardened by heating it to a dull red heat, and then plunging it, point downwards, into a tub of cold water. Then it is drawn through the fire, until the previously polished surface acquires a blue tint from the thin, superficial, iridescent film of iron oxide that becomes thicker and changes color according to the degree of heat. Then the sword is allowed to cool. The hardening expands the steel, but more rapidly on the surface than in the interior, occasioning strains; and so, too, with the corresponding contraction caused by the annealing. Hence, the implement is apt to crack, split, bend or "buckle," or get out of shape, and special precautions must be taken to keep or restore the proper form.

In Japan, the temper is given by a single process. What is desired for the sword is a hard edge, capable of being keenly sharpened; but a body and back far less brittle, though not soft, flexible and inelastic, like iron.

The blade is first coated with loam $\frac{1}{8}$ inch thick, a loam that bears the heat well, mostly a red earth called rust-mud, mixed with an equal quantity of the finest powdered river sand and one-tenth of the finest powdered charcoal, or with other things. Many smiths make a secret of the composition. Before the loam coating is quite hard, a narrow streak of it along the edge of the blade is carefully removed with a bamboo rod, so as to leave the edge bare. The rest is dried before the fire.

The smith then holds the blade in his right hand, by the tang, with pincers, and thrusts it horizontally, edge downwards, into the hottest part of a strong fire of pine charcoal of a special quality, called forge-coal, while his assistant—or he himself, with his left hand—regulates the heat by the bellows. The blade is moved slowly backwards and forwards, in order to be uniformly heated throughout its whole length. The part next the tang is often drawn gently out of the fire, so that the master's practised eye may judge, in the carefully closed and darkened smithy, when the right degree of heat has arrived. It comes in a few minutes, and the sooner the better, so that the loam covering may not have time to get overheated through and through.

The blade is taken from the fire and plunged immediately into cool, lukewarm water, of a temperature and during a time determined by the smith. Each smith has his own way. The sudden chilling hardens the bare edge, and makes it capable of great sharpness, though very brittle; and the color becomes whiter than the darker, bluish tinge of the rest of the blade. The loam protects the rest of the blade from too great heat in the fire, and now from too sudden chilling in the water; and so the desired temper for the body of the sword, sufficient hardness, stiffness and elasticity, with toughness, too, is obtained by the same operation that gives the still greater hardness to the edge.

The narrow strip left bare at the edge for hardening is called the baked-edge (*yakiba*), and is not always of the same breadth or shape, but differs according to fancy, and thirty or more varieties are distinguished by special names. A very broad baked-edge is not desirable, for too large a part of the blade would be brittle. Consequently, a narrow, straight hardened edge, or a simple irregular one is generally preferred and the commonest. Among other forms there is no preference, and they show nothing of the quality of the sword. They depend on the smith's or the owner's fancy, and somewhat on fashion, and in times of long peace the more complicated forms are apt to be preferred. In some degree they help to identify the maker; for, though celebrated smiths used various forms, connoisseurs know which forms each master

most used. The bounding line of the hardening at the point of the blade gives rise to eight or more different forms and names.

The expansion of the edge from the sudden cooling in the bath causes a curved sword to bend somewhat further, and to a degree dependent partly on the manner of dipping the blade into the water. A straight sword is plunged vertically downwards. A curved one is let down horizontally into the water, with the edge down, either suddenly or slowly, either evenly or with the point slightly lower at first and rising from the water as the tang goes in. If the blade curves too much, or, by bad holding, bends sidewise, it can be heated and hammered again, but with no benefit to the quality.

Smith's Finishing.—The tempered blade is carefully cleaned and roughly ground on a coarse stone. The smith then, for the first time, sees whether the blade is a success or not. If it be satisfactory, he next cuts the grooves, if any, with a steel graving tool, giving an exactly semi-circular cross-section. The grooves lighten the sword, and are found in some of the oldest specimens.

Many smiths adorn their swords with engraving, especially with dragons, gods, flowers, Chinese or Japanese characters and Sanscrit letters, or the name of the sword itself, if it have one. But, as such engraving sometimes serves to conceal blemishes in the blade, it is not always liked by connoisseurs.

The smith drills a hole through the tang for the bamboo or metallic peg that holds the hilt on. He sometimes cuts his name on the tang, and the custom existed already about 1,200 years ago, but has often been neglected. Poor swords commonly have no maker's name; but, again, some famous makers would not put their names on, because, they said, anybody that understood swords would recognise theirs by the quality. With the name on the tang are often given the title and the date, and sometimes the owner's name and the name of the sword itself, if it already had one when forged; and, again, poems, pithy sayings, or wishes. It should be remembered that inscriptions of makers' names are sometimes counterfeited.

The most famous sword-maker was Masamune (about A. D. 1290); and, next, his pupil, Muramasa (about 1340); then Yoshimitsu (about 1275); and Munechika (about 990). Of Masamune's swords it is often said they are so fine they will cut a hair falling in the air, or cut in two the very hard-skinned adzuki bean as it falls; or, if held in a stream, will cut in two a sheet of paper floating down. The swords of Muramasa are said to be so finely tempered as to cut hard iron like a melon.

The first reported human swordsmith is said to have been Amakuni, of Uda, in Yamato (about 60 B. C.); but the oldest known swords, some of them still extant, were made by another smith of the same name and place, about A. D. 702. The Emperor Gotoba (1184) greatly favored the art of sword-making, and even practised it himself. In general, the art flourished in times of many wars, particularly in the thirteenth and fourteenth centuries, the age of the best swords. For the past 300 years of peace mainly, skill in sword-making has declined. Old swords, so-called, date from before that time, that is, before 1603.

Grinding.—The final grinding and polishing of swords is a trade quite distinct from the smith's. The grinder holds the blade horizontally before him in both hands, protected by cloths wound about it, with a narrow portion left uncovered between. He rubs it back and forth on a small whetstone well wet with water, moving by degrees through the whole length of the blade, except the tang; first, with coarser stones, then with finer, up to four, six or eight, for ordinary work, or, for very fine work, fifteen stones; giving to it many days and even weeks, as well as great patience, skill and care. The cross-section of the blade should be left convex on both sides; otherwise, the edge is too easily broken.

Lastly, the blade is polished with a polishing stone, and with a stone powder as fine as flour, or with the finest powdered steel, forge cinder and oil, as also with a small, round rod of wrought iron, until the polish is perfect. Winter is preferred to summer for polishing, as newly polished swords are thought to rust too easily in summer.

Swords ought to be carefully oiled and rubbed now and then, as often as twice a year in Japan, and very valuable swords, perhaps, once a month. Otherwise, moisture in that damp climate condenses on them and causes rust. Above all, they ought not to be kept uncovered by a scabbard of some kind. For this reason they cannot well be displayed in museums. Every sword, in the course of years, needs a slight grinding, from time to time, and the selection of a good grinder is very important, and some grinders have great reputations.

Sword-grinders, with their close and protracted observation of swords in grinding, become almost incredibly skilful in detecting the signs of the quality of a blade, and in recognising the make of the numerous celebrated masters. The most famous connoisseurs belong to the sword-grinding family of Honnami, who have been the imperial sword appraisers for the past 550 years.

Not only do the shape of the blade and its point, the form of the limit to the hardened edge, and the file marks of the tang give indications of the origin of a sword, but it is astonishing how many clues are found by an extremely close examination of the surface of the metal, thoroughly homogeneous, close-grained and intractable as it seems at first view.

The more strongly the whitish color of the hardened edge contrasts with the bluish tinge of the rest of the blade, the better the metal and its forging; yet the limit between the two colors should not be hard and sharp, but softly bounded; and that is partly caused by a weak, cloudy glimmer in irregular spots (called *nioi*, vapor) along the union of the brighter hardened and the dark unhardened portions. Partly in the one, often to the very edge, and partly in the other, they are found in all blades, and only in a poor one are rare. They arise during the hardening, and vary in number and character according to the quality of the metal and of the forging and to the temperature of the last heating, and cannot be counterfeited. It is thought best they should not be uniformly scattered, but in thicker and thinner groups, like the clouds in the sky.

If the loam covering, while the blade is moved back and forth during the heating, becomes thinner in some spots or loose, so that the heat of the fire and subsequently the chilling of the bath work more strongly, there arise in the surface of the blade isolated, cloudy spots, called *tobiyaki* or *yuhashiri*. They cannot be produced on purpose, are rare, and are seen with satisfaction.

The "grain" on the surface of good swords should be soft and tender, "as if water rippled over the metal."

A certain degree of heat very favorable for the hardening, as well as especial success in the chilling, produces on the surface of the lighter colored, hardened edge minute shining points, called *nie*. According to some, they arise from bubbling in the water. They are often very difficult to perceive, and sometimes even a connoisseur requires a magnifying glass to discern them. They are reckoned a sign of good quality, and occur on most of the better blades, and especially in large number on Masamune's.

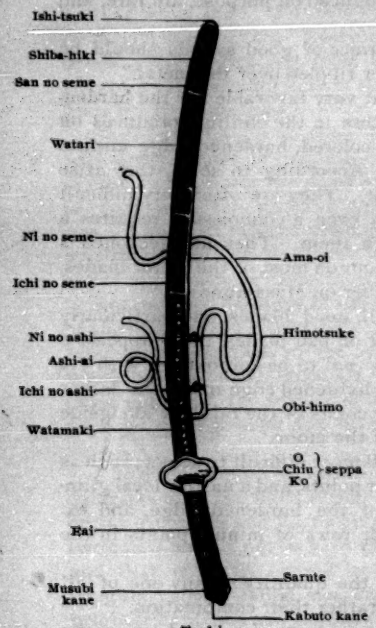
On many, though not all, good blades, and particularly on those of Bizen, but never on bad blades, there appears a weak glimmer, called *utsuri* (not to be confounded with the *nioi*), running parallel to the hardened edge inside the darker metal, and resembling "the colors of the rainbow alongside one another and the halo of the moon."

There are other signs still more difficult to detect; such as certain small cloud specks or points, and a narrow local glimmer along the boundary of the hardened edge, and extremely fine shining lines or rows of minute points in the *nioi*.

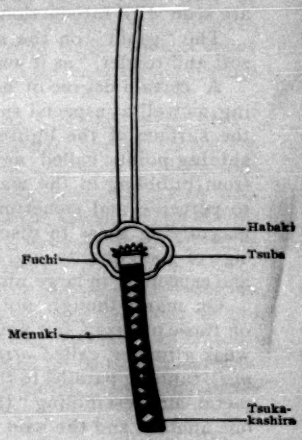
Neither the quality nor the quantity of any one of all these signs is decisive, but rather their combination.

Testing.—The usual Japanese tests of a sword are on the human body; on corpses of beheaded convicts, or in the beheading; or by ruffians, on beggars and peaceable wayfarers; or even on a dog. But Hütterott, from whose elaborate account many of the foregoing facts about Japanese blades have been taken, in his zeal, tested some good swords on metal. With a blade of Mino he cut through, at one blow, without injury to the edge, five *tempô* coins piled one

on another, in all a full $\frac{1}{2}$ inch thickness of bronze, and $1\frac{1}{2}$ inches wide. The same sword, struck upon a piece of hard wrought iron about $\frac{1}{4}$ inch thick and over $\frac{1}{2}$ inch wide, cut about $\frac{1}{8}$ inch deep and became notched. At a second stronger blow it cut about the same depth and broke in two



Tachi.



The Hilt (Tsuka).

The Guard (Tsuka).

at the point struck. A good Satsuma blade could only cut through four *tempô*, and broke at the third blow on the wrought iron, after getting large notches by the two other blows without cutting very deep; but an inferior Kiyoto sword, that could only cut through three *tempô*, endured three blows on the wrought iron.

Mounting.—The finished blade may be mounted with a hilt, a guard, a ferrule and a scabbard, and the scabbard has certain fittings. The different parts have each its own name, and many of them are made highly artistic, particularly the guard, the metallic ferrules about the hilt and scabbard, and the metallic handle of the small knife inserted in the outside of the scabbard of many short swords. The knife is used as a last resource, to throw at

Scabbard for Tachi.

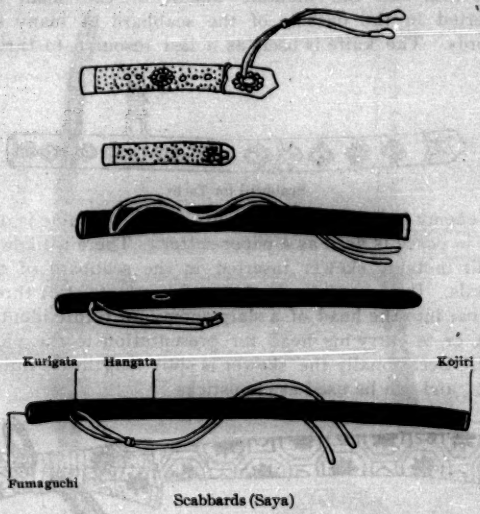
the enemy in battle, or to cut his throat when he is down, and in peace is used as a paper-cutter. There is likewise a small metallic skewer inserted in the scabbard of those swords. It is used, in the heat of battle, to stick through the ear into the head of a slain enemy for future identification, or to carry his head for presentation to the victor's lord. Occasionally the skewer is split lengthwise into two parts, and can be used as chopsticks.

Brocade Bag over a Sword.

Etiquette.—The Japanese owner of the sword honored it highly, and many and minute were the rules of etiquette as to the way of treating and wearing it; and they were most strenuously insisted upon in former days, though they have now mostly fallen into disuse.

In fine, the Japanese sword must be admitted to be as beautiful and interesting an object as the processes of its

manufacture are ingenious and skilful. Though not of the most effective form, it must always rank high among the weapons that will ever be needful as long as men exist who are naturally, or by training, so deficient in good-will or reason as to be amenable only to forcible restraint.



Scabbards (Saya)

[Japanese swords are discussed by the author more fully in the *Proceedings* of the Numismatic and Antiquarian Society, of Philadelphia, for 1890–91. The illustrations herewith, copied from Japanese books, have been kindly loaned by that Society.]

GRAPHICS OF THERMODYNAMIC LAW.

By R. H. Thurston.

The geometry of thermodynamics, and especially the graphics of heat and work transformations, may often be found to permit the employment of methods of elucidation of the principles of the science which are far more satisfactory to the average mind than are algebraic formulas. The latter are peculiarly difficult to follow, in the case of the majority of students of this subject, although absolutely logical, exact and positive; while the picture of the law, or of the fact represented by the graphical construction, often gives to the mind a thoroughly satisfactory idea, and a real conception of the physical quantities and the phenomena considered. The writer has, at times, employed such methods of representation in the development of the whole elementary basis of thermodynamics, as well as, frequently, in the discussion of special problems; some of which latter, in fact, while easily and readily treated by the graphical method, cannot be fully treated, at all satisfactorily, by any algebraic system.

In illustration, compare the method of application of the logical, syllogistic method, of the algebraic process, with the graphical system in the expression of the laws of thermodynamics, and in the deduction of the two principal forms of the "general fundamental equation." The logical process, as here referred to, is the following:

Propositions.—(1) The science of thermodynamics considers those phenomena of physics which involve only thermal and dynamic operations in mutual relations.

(2) In such phenomena the processes in action involve only displays of thermal energy, of dynamic energy, and of transformation of the one form into the other, in either direction.

(3) A given amount of energy being available and acting, it is a total consisting of two parts, thus:

$$E = H + W; \qquad (1)$$

in which E is the total energy, and H and W and the two parts the thermal and the dynamic energy, of which it is made up in all cases, whether of supply or abstraction. Either term of the second member, or both terms, may be either positive or negative; positive indicating supply or gain, and negative indicating abstraction or loss of energy, by the system. Heat is always measured by the product $K_v d\,t$, of the true specific heat of the substance which is its vehicle and the range of temperature, in this case assuming an elementary change. Work, or dynamic energy, is always capable of being measured by an equivalent of the form, $p\,dv$, the product of the intensity of an unbalanced pressure in a fluid into the volume through which it acts, also here taken as elementary. Assuming a common measure of the unit of energy, as the foot-pound or the kilogram-meter, we may thus at once write out, as a deduction from the above principles, which, in fact, also assume the first law of thermodynamics, the quantivalence of energies, the general fundamental equation of thermodynamics, as above.

Stating the first law of thermodynamics as follows, the same algebraic expression may be at once written out:

Energy received or expended in either form is equivalent to the algebraic sum of that applied, in any thermodynamic operation, to producing change of temperature, and that applied to the production or reduction of work.

This statement is the verbal equivalent of the equation above.

Assuming, as the simplest case, the thermodynamic operation to be one in which heat is applied to the simultaneous increase of the temperature of a gas and the development of mechanical energy, by its expansion behind a piston, we have the above equation in the form

$$dH = K_v dt + p\,dv; \qquad (2)$$

which is the familiar first form of the general equation, as given by Rankine and by Clausius; the assumption being that the energy received by the gas may be supposed to take effect, first, in raising temperature, simply; secondly, in

the development of mechanical energy, or the performance of work at constant temperature of working fluid. The work may either be that of internal molecular disturbance, or that of external displacement of an enclosing mass, as of "latent heat," L, or of sensible work, U.

Dividing the expenditure of energy into these several forms,

$$dH = K_v dt + dL + dU; \qquad (3)$$

which is one of the forms given it by Clausius.

Comparing (2) and (3), it is seen that the factor p in the first measures the sum of the two forces resisting expansion in any mass, the one internal and cohesive, or molecular, the other external, confining pressure, as measured by a pressure gauge.

The second form of the general equation, as given by both Rankine and Clausius, comes directly from the first, thus:

In the "defining equation" of a gas, $pv = Rt$. When pressure is constant, as assumed in the construction of the first of the above forms involving t, the relation becomes $p dv = R\,dt$, and when t is constant, $p\,dv = -v\,dp$. Make t and p the independent variables, and it may be shown that

$$dH = K_v dt - v dp; \qquad (4)$$

which is the second form of the general equation, as developed by both Rankine and Clausius. It is in the production of this form of the equation that a graphical method becomes especially satisfactory, as enabling the mind to follow the process, easily perceiving the relations of the quantities here variable. Rankine made much use of graphical methods in the discussion of thermodynamic and other problems, and his success is probably largely due to this fact. He has not, however, employed this system in the case here studied.

In the succeeding figures, let $A\ B$ represent a path along which the working fluid is carried, in any thermodynamic operation. Assume the action to take place by a series of

elementary steps: as, *Fig. 1*, changing pressure at constant volume, on one isometric line, $A\,a'$, then changing volume at constant temperature, on the isothermal $a'a$, and again by ab' and $b'b$, and so on, until B is reached. It is evident that each elementary step, along the path AB, as Aa' or ab', is accomplished by expending quantities of heat energy at constant volume, measured by the product, for each unit weight of working fluid, $K_v dt$, and a quantity of work—no heat being accepted by the substance on the isothermal—measured by $p\,dv$, the equivalent of the heat-energy transferred from the source during the period of isothermal

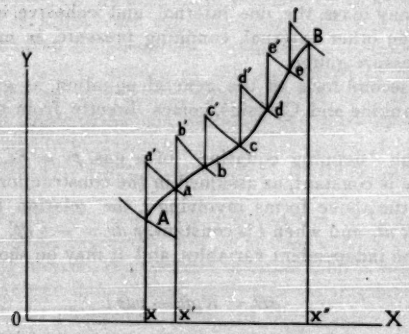


FIG. 1.—With V and T variable.

change. Thus, the whole quantity of heat energy demanded at each elementary step, ab, is

$$dH = K_v dt + p\,dv; \qquad (5)$$

which is the first form of the general equation of thermodynamics, and the method of its derivation, thus illustrated graphically, is easily followed.

In the second case, take the elementary steps in heat supply, as indicated in the second of these figures, first at constant pressure, from A to a, *Fig. 2*, at constant temperature from a to a', and so on. But, in the second of these steps, the work performed becomes negative, as reckoned in our

algebraic work, and we have the second form of this equation:

$$dH = K_p dt - x'' aa' x'. \qquad (6)$$

But, since $a\,a'$ is an isothermal, in other words, an equilateral hyperbola,

$$y_a x_a = x_a' y_a';$$

and, deducting the magnitude $y_A x_A$ from these equal quantities, and the common magnitude $A\,f\,x'\,x$ from each of

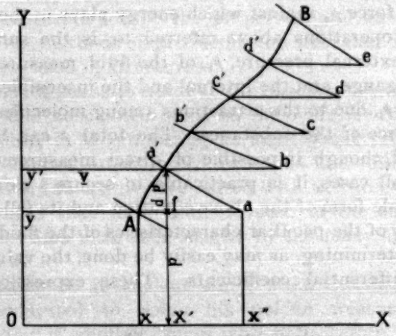


FIG. 2.—With P and T variable.

these differences, we obtain the equality, after adding faa' to both sides,

$$x' a' a\, x'' = y' a' a\, y;$$

in which expression the second member represents $v\,dp$.

Thus, equation (6) becomes

$$dH = K_p\, dt - v\, dp; \qquad (7)$$

which is the second form of the general fundamental equation of thermodynamics, and its peculiar construction thus becomes readily understood.

It is thus possible to derive the expressions of Rankine and Clausius, in these two principal forms, by graphical

construction and by reference only to the first law of thermodynamics.*

The second law enables us to extend the application of these equations to the more obscure cases of the non-gaseous substances, in which the existence of internal and sensible forces acting between adjacent molecules makes conception and application alike difficult. According to the second law of thermodynamics, as already seen,

$$p = t\frac{dp}{dt}; \tag{8}$$

the total force p, against which energy plays in the thermodynamic operations above referred to, is the sum of the sensible external pressure, p_e, of the fluid, measured by the pressure-gauge, and the internal and the insensible internal pressure p_i, due to the attractions among molecules, the cohesive force of the substance. The total p can be easily computed, though impossible of direct measurement, and thus, in all cases, it is practicable to secure a correct and manageable form of the above equation and its fellow, independently of the peculiar characteristics of the fluid, by first simply determining, as may easily be done, the value of the partial differential coefficients. These expressions thus become

$$dH = K_v\,dt + t\frac{dp}{dt}\,dv; \tag{9}$$

$$= K_p\,dt - t\frac{dv}{dt}\,dp; \tag{10}$$

which are the familiar and most general forms of the equations.

* Professor Wood employs the graphical method extensively, and his method of thus deriving the second from the first form of this equation is particularly elegant.—"Thermodynamics," § 45.

STRUCTURAL STEEL.*

By James Christie.

The lecturer was introduced by F. Lynwood Garrison, Professor of Metallurgy Economic Geology in the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

In this brief discourse, I will endeavor to describe in a popular manner a few of the properties, and an outline of the existing methods of producing the steel that is now so extensively used in structures.

We cannot pause to examine the obsolete systems which have formed successive steps in the evolution of the art. Their history is as interesting as any romance, recounting the old story of intermingled triumphs and failures; and the pages of the century are dotted with the wrecks of lives and fortunes that have been devoted to the solution of problems which have been sought by the many and solved by the few.

According to an ancient story, when Crœsus, King of Lydia, exhibited to Solon his golden treasures, Solon remarked: "If another comes who hath better iron than you, he will possess all that gold." He indicated then what is fully recognised now, that the quantity of iron produced and used is an index of a people's power and prosperity. Iron, in any form, had no widely extended application until this century, during which the statistics of increase of production tell their own story. Prior to thirty years ago, steel, even of the lowest grades, was a comparatively expensive metal; its use was confined to tools and minor purposes, for which its strength and hardness gave it preëminent advantages over wrought iron.

About thirty-five years ago, Henry Bessemer predicted that the age of steel would supersede the age of iron, as

* A lecture delivered before the Franklin Institute, December 6, 1895.

surely as iron displaced the supremacy of bronze. Bessemer is still living, and his prediction is already verified. For the leading applications in which the malleable forms of iron are used in the arts, steel has so largely displaced iron that, of the 10,000,000 tons of pig iron, which is now approximately the normal annual product of this country, about one-half is converted into steel, and the puddling furnace has ceased to be an important factor in the production of structural metal.

It is desirable here to define what is meant by steel; for there is some vagueness and uncertainty in its accurate definition, and much of what we choose to denominate steel is known in some places as ingot iron. Indeed, it is possible to have two metals, yielding identical results by chemical analysis, one of which may be true fibrous wrought iron, and the other what we know as steel. The sole difference would be in the molecular structure, and this difference would be determined by the temperature employed in the conversion of the malleable metal from its primitive form. To understand this, it is necessary to remember that, in a general sense, the character of the metal is determined by the amount of carbon that is associated with it. To have wrought iron, the content of carbon must be very small; as the carbon content increases, the iron assumes the steely character. By increasing the proportion of carbon in the iron beyond certain limits, the metal loses its malleability and becomes cast iron. In this instance we have one of those curious anomalies frequently found in the arts, where a substance whose melting point is very high, or even when it is practically infusible, when united to some other substance, acquires by such union the property of melting at a lower temperature than that of either of its component materials. The purer iron is—that is, the freer it is from the extraneous metals or metalloids that are usually associated with it—as a general rule, the higher will its temperature be at the melting point. Therefore, in the puddling process, as the excess of silicon and carbon is reduced in the molten metal, a point is reached, at the regulated temperature of the bath, where the metal approaches to the condi-

tion of pure iron and lies in the liquid slag as a pasty, viscous mass, and in this condition is handled and finished. This process may be termed one of agglutination. On the contrary, when steel is to be produced, the temperature is kept high enough to maintain the molten condition, and it is produced from the crucible, or the converter, or the open hearth furnace, in the molten state, but is malleable after solidification; hence, steel-making may be termed a fusion process. Therefore, when we speak of structural steel, in contradistinction to structural wrought iron, it should be understood that the distinction lies in the mode of manufacture (the former being prepared by fusion, and the latter by agglutination), and not necessarily in any essential difference in the composition of the metals.

During the puddling process the iron will not agglutinate until the extraneous elements, principally carbon and silicon, are almost entirely removed. Minute proportions of injurious elements, principally phosphorus and sulphur, may remain associated with the iron to its detriment; but, broadly speaking, in wrought iron properly worked, there is little variation in its physical properties; its tensile strength will not vary very much either way from 50,000 pounds per square inch of sectional area, and it remains nearly uniform in hardness. On the contrary, by the fusion process the finished metal may retain carbon varying from nothing to 1½ per cent. or more; it may also contain, by choice or necessity, a considerable proportion of manganese or silicon. Its tensile strength may vary from below 50,000 to over 150,000 pounds per square inch of section. It may be softer than ordinary iron produced by agglutination, or it may be the hardest tool steel; yet in all its gradations, which insensibly merge together, it possesses certain characteristics which are common to all its grades, so that we cannot discern any dividing line, and assert that all metal on one side is steel, and on the other side it is not steel. It is true that a class of steel can be, and has been, largely converted from the condition of wrought iron without fusion, but that is a branch of the subject we are not considering now.

Of the numerous methods that have been proposed and

tried for producing cheap steel, but two remain, and by these two methods all structural steel is now made.

One is the pneumatic process, due to Bessemer, by which a stream of air is forced through a mass of molten pig iron in a suitable vessel, and the excess of carbon and silicon in the crude metal is rapidly burnt out. At the same time, the temperature is raised so high that fluid steel remains, and is thence cast into ingots to be subsequently finished in the mill or forge.

By the other process, largely due to Martin, a mixture of pig and wrought metal, or pig and iron ore, is melted in the shallow saucer-shaped hearth of a reverberatory furnace, and subjected to an intensely hot flame. In order to obtain the intense heat necessary, the furnace is almost necessarily of the regenerative form devised by Siemens, and the resulting fluid steel is cast into ingots and handled as in the pneumatic process. The steel produced by these two distinct methods is so alike in all its characteristics that one cannot be distinguished from the other by ordinary appearance or analysis, although it is claimed that a difference can be detected by refined microscopic examination. Conversion by the Bessemer process is so rapidly completed, that it is not practicable to control the desired character of the product in the precise manner in which it is done in the open hearth furnace, from which samples of the metal can be taken and tested, and the carbon content of the molten mass raised or lowered, as desired.

By the Bessemer process the silicon and carbon of the molten pig are almost entirely burnt out, and the metal is finally recarbonised to the desired extent by the addition of sufficient spiegel or ferromanganese. By the open hearth process (at least in the acid process), reduction is stopped when the content of carbon is reduced to the proper amount for the grade of steel desired; hence, open hearth steel is preferred for purposes where a specific character is desired for the metal.

There is always found associated with iron certain elementary substances, metals or metalloids, a dozen or more in number. These combine as alloys or solutions, very

much as copper, tin, zinc, etc., unite to form the bronzes. Some of the gases also are believed to be dissolved in steel, the nature and effects of which are imperfectly understood. The majority of these constituents existed in the ores as they were originally formed in Nature's crucible; a few of them are added during the process of manufacture, for specific purposes. Each of these constituents contributes to the strength and hardness of steel. This statement has been disputed and denied, but the weight of evidence tends to confirm the belief that each element adds something to strength, although they vary very much in their strengthening influence. The strengthening effect conferred by some constituents, hereafter given, has been shown by the results of extended investigations made by W. R. Webster, a member of the Institute. These results, it will be understood, are applicable only to the limited proportions of these foreign elements, usually to be found in commercial steel.

The purest iron that has been produced is a comparatively weak and soft metal. Perfectly pure iron, if it could be produced and properly forged into small bars, would have a tensile strength of less than 40,000 pounds, and probably not over 35,000 pounds, per square inch of sectional area. Of the constituent elements, some are rarely absent, others rarely present; some exercise a beneficial, others an injurious influence. The exact effect of some of the constituents has been a subject of much dispute, and authorities do not agree entirely on the subject. Some of these substances unite with iron only to a limited extent, when the metal is said to be saturated; others unite to any extent, even so great that the iron ceases to predominate, and is no longer known as iron, but takes the name of the predominating metal.

An eminent authority wrote a few years ago that he was convinced that the composition of steel is not an accurate index of its physical properties. Whilst this may be true to a limited extent, yet it is evident that the tendency in modern open hearth practice is to produce metal of more uniform composition than formerly, varying the carbon content according to the tensile strength or hardness desired,

with the result that the physical properties are also more uniform than before. It is probable that each element modifies, to some extent, the influence of others, so that the interplay of the whole, due to varying proportions, becomes a matter of great complexity.

Carbon is the principal hardening and strengthening agent, and is purposely retained in combination with iron to the desired extent, according to the grade of steel required. Each 0·1 per cent. adds to the tensile strength of the metal about 8,000 pounds per square inch of cross section. Its hardening influence can readily be detected even on the very softest grades of steel. Test specimens containing 0·1 per cent. carbon, when chilled from a red heat in water of ordinary temperature, will show an elevation of the tensile strength averaging about 20 per cent. These hardened specimens are still so ductile that they can be doubled flat without fracture. With a carbon content of 0·15 per cent., the hardened specimens will occasionally crack, but usually bend nearly flat without fracture. With carbon 0·20 per cent., specimens will occasionally bend 90° or more, but usually crack. With 0·25 per cent. carbon, the steel may be expected to always crack. Above 0·40 per cent. carbon, we get steel suitable for low-grade cutting tools.

These physical properties belong to steel, in which the proportions of hardening agents, other than carbon, do not exceed the usual average in structural steel of approved quality. Manganese might be denominated a necessary evil, for it has not been demonstrated that it is directly beneficial to the steel in service; and for many purposes where the steel is necessarily subjected to destructive action, the lower the manganese the better the steel endures the punishment. But steel by the ordinary process cannot be continuously and economically made without the addition of manganese. It is supposed to eliminate or neutralise certain oxides, which are imprisoned in the fluid metal, and it is also believed to mitigate the injurious influences of the other elements that are usually present. It increases the tensile strength of the steel from 1,000 to 2,000 pounds per

square inch of area, according to conditions for each 0·1 per cent. of manganese. It is ordinarily present in structural steel to the extent of 0·40 to 0·80 per cent., and is apt to cause the metal to be sensibly brittle if it much exceeds the latter proportion. It tends to reduce the magnetic property of iron, and when the alloy contains about 10 per cent. of manganese, the metal becomes practically non-magnetic. Manganese is always put into steel at the end of the heat, in both the Bessemer and open hearth processes.

The use of manganese in the manufacture of crucible steel was introduced by Heath, in England, about sixty years ago. It soon demonstrated its utility in correcting the injurious effects of foreign elements in iron, and permitted the extended use of cheaper and impure stock, especially in the lower grades of steel. Smiles says that the immediate effect was to raise the annual production of steel in Sheffield from 3,000 to 100,000 tons. Owing to a defect in Heath's patent, the process became public property without compensation to its discoverer.

Mushet, twenty years later, had a similar experience. He patented the use of manganese in the Bessemer process, making the method practicable. Mushet allowed his patent to lapse, by failing to pay the annual fee required in British patent law, and failed to obtain just pecuniary award for his important discovery, although an annuity was paid him by Bessemer, as an act of personal generosity.

Silicon may be found in minute proportions in steel as a residual constituent of the pig iron, but usually comes from the addition of ferrosilicon to the molten metal. It has the same property as aluminum, which has largely replaced it, of quieting or reducing the ebullition of the molten steel, and hence promoting soundness in ingots and castings. The percentage of this element need not exceed 0·1 per cent., but a greater amount is sometimes tolerated in steel castings, on account of the soundness it confers. Its strengthening influence is not definitely known, but it seems to exert a lower effect than manganese. Copper is frequently associated with iron in the ore, and clings tenaciously, throughout the various stages of manufacture, to

the finished steel. It has always had the reputation of causing red-shortness, or brittleness at red heat. It is frequently known, however, to be present as high as 0·25 to 0·5 per cent., without causing much trouble. Some consider it especially injurious when associated with an excess of sulphur.

Sulphur is an element which it is always desirable to reduce to the lowest limit. It makes the metal short, or brittle, at red heat, and, consequently, difficult to forge without cracking. It should not exceed in proportion an upper limit of 0·1 per cent., and recent specifications frequently reduce this one-half, or more. As a hardener, sulphur raises the tensile strength of steel about 500 pounds per sectional inch for each 0·01 per cent. of the element present in the steel.

Phosphorus is the agent of evil most to be dreaded in steel. In the early days of Bessemer steel, it was found to be the principal insidious spirit of mischief that gave the metal the reputation of being capricious, treacherous, etc., and as it is widely disseminated throughout the principal deposits of iron ore, the efforts of the iron manufacturer have been ever exerted to keep the quantity within proper bounds. It is an active hardening agent, and is believed to increase tensile strength from 1,000 to 2,000 pounds per sectional inch, for each 0·01 per cent. of phosphorus in the steel.

Phosphorus has an intense affinity for iron, and as it burns to phosphoric acid when united with oxygen, it requires the presence of a highly basic flux to induce it to part company with the iron. Unfortunately, the silicious materials, which have always been used as the most cheap and useful refractories for forming the sides and bottom of furnaces, produce a slag, the principal component of which is silicic acid, and incompetent to seize the phosphorus.

It has long been known that mineral bases were abundant, and sufficiently potent for dephosphorising; but it is only in recent years that practical methods of selecting and preparing the material have been developed. Within the memory of men still living, iron was puddled in furnaces,

whose sides and bottom were silicious, or acid, in the chemical sense, and therefore the slag in which the malleable metal was reduced was incompetent to seize phosphorus or sulphur. Metal fit to use could only be obtained by careful selection of suitable ores, which, in time, as consumption increased, became scarce and expensive. One of the most important improvements in the manufacture of wrought iron consisted in forming the hearth of the puddling furnace of iron plates, which were lined with iron ore; and a floor of slag, rich in oxide of iron, was prepared, on which the charge of pig iron was treated. This was a true basic process, and permitted the production of excellent iron from material that would have proved useless if made on the old sand bottoms.

The oxide of iron lining was not sufficiently refractory, nor otherwise suitable, to endure the high temperature of molten steel. Compounds of lime and magnesia, as found in the highly basic minerals, dolomite and magnesite, are now successfully used as linings for steel converters and furnaces, and to withstand the scouring action of a lime flux, which forms a basic slag, that compels the iron to part with its excess of phosphorus, and also with a part of its sulphur. Excellent basic steel is now made from material that could not be tolerated if washed by a siliceous or acid slag. The basic Bessemer process, though very little used here, is extensively used in Europe, especially in Germany, where, owing to the prevalence of phosphoretic ores, it was much needed. The basic open hearth furnace is in extensive use here, and promises to largely supersede the acid process.

The great impetus given to the production of structural steel in recent years is due, not to its superiority over good wrought iron, but to the fact that it can be produced more cheaply. The peculiar circumstances under which wrought iron is produced do not admit of the application of the perfect mechanical appliances for manipulating the metal, which are distinguishing features of modern steel works. It is usual now for structural material, such as plates, angles, beams, etc., to be finished without loss of the initial

heat acquired in melting. The red-hot steel ingot passes through one, or at most two, reheating furnaces, which merely revive the fading glow on its passage through the blooming and finishing mills, and during this transit it is handled by suitable mechanism, and with so little muscular effort on the part of the workmen, that the toilsome labor that was formerly considered the inevitable lot of the iron-worker promises to be known only as a tradition.

Heavier and stronger machinery is used in the mill than was customary with iron, partly because the working heat of steel is lower than that of iron, partly because its resistance to rolling when hot is greater than that of iron, somewhere about the same ratio as the comparative strength of the cold metals, and also because the larger masses handled and the celerity of modern process demand stronger machinery. Steel castings, in the make-up of the mill appliances, have become a necessity. Steel is frequently quoted as a more homogeneous metal than wrought iron. This is only true in a limited sense. It is produced in larger single masses, free from weld or similar union, and to appearance is more uniform and works with less distress than is usual with wrought iron, but the very fact of the necessity of forging puddled iron into thin bars, and piling and reworking to make a finished product, insures a solidity that is not so certain, when the fluid mass is cast into large ingots.

As is frequently found when large masses are solidified from a liquid condition, cavities are liable to be left in the interior, during the process of crystallisation, unless the most approved methods are used. These cavities may remain a concealed source of weakness, especially in finished products of large dimensions.

Further, the extraneous elements in the steel tend to separate in the quiet fluid mass immediately before solidification, therefore the analysis frequently differs considerably at the opposite ends of an ingot. This separating tendency is intensified near the middle of the mass, where final crystallisation occurs, and there is always more or less segregation at this point, frequently resulting in a mass of steel whose composition is dangerously bad. In this sense steel cannot

be denominated more homogeneous than properly worked wrought iron.

Around the center of segregation in the steel ingot, there may be a mass of metal in which the separated constituents have gathered, making it a bad, possibly a worthless, part of the metal. If the ingot is forged into a shaft, the segregated mass will probably be drawn out to a slender core along the central axis. There is, therefore, a practical advantage in boring a hole through the center of important shafts, as it probably removes a segregated core. If the ingot is rolled into a flat bar or plate, the segregated mass may spread out into a considerable area, whose location would be difficult to detect. No effective means have been adopted to insure the absence of segregation. For guns and armor, the United States Government requires sufficient of the top of the ingot to be rejected as will discard the segregated mass. It has been proposed to limit the cross sectional size of ingots; to cast as cold as practicable, in order to hasten solidification; or to submit the ingots to a clasping compression before the center is solid, and thus scatter or squeeze out the objectionable part. Doubtless, means will be adopted to prevent what is a not infrequent source of trouble.

In the workshop the treatment of steel is very similar to the old practice with iron. The more common use of the drill and rimmer, and the milling machine, is not due so much to necessity as to a growing appreciation of, and demand for, better work than was customary in former years.

Now, the laboratory and the testing room are important adjuncts of every steel works, and the chemist and the inspector are always to the front, ready to criticise or condemn.

In the forge, welding is abandoned for all work of vital importance. Work is either produced from the original solid, or else built up by riveted or screwed connections. The harder grades of steel are welded with great difficulty, and even the very softest grades are not susceptible of true welding, in the sense in which the term is applicable to

fibrous wrought iron. Important forgings, whose treatment requires local heating and manipulation, are annealed by being bodily heated to a uniform temperature and uniformly cooled.

In the endeavor to obtain the most suitable metal for a purpose, some specifications confine the conditions to results of physical tests, others add chemical requirements in which a limitation is prescribed for certain combining elements, and there is a growing tendency to the latter system. It is maintained by some, as the exact effect on the steel of the union with extraneous materials is not positively known, that conformity with a high standard for physical requirements is sufficient, and that the manufacturer is only embarrassed, and the object to be gained not insured, by asking more. On the other hand, it is claimed that the ordinary physical tests do not fully disclose injurious influences, which may manifest themselves under the imperious demands of hard service. Moreover, the lower the ratio of the elements which bring a possibility of danger, the less is the risk of having these elements in injurious excess within the area of segregation.

The engineer is always compelling the manufacturer to give the best results, and doubtless has created a higher standard of excellence than would have existed under easier requirements; but frequently specifications are presented whose fulfilment is almost impracticable, and friction and delay compel an abatement of unreasonable demands.

Structural steel for buildings, bridges, etc., of excellent quality, will analyse as follows: Carbon, 0·10 to 0·25 per cent.; manganese, below 0·60 per cent.; silicon, below 0·10 per cent.; phosphorus and sulphur, each below 0·06 per cent.

Tensile tests on bars of moderate section should yield an ultimate strength varying from 55,000 to 70,000 pounds per square inch of section, according to carbon content; elastic limit not below 0·6 of the ultimate strength; the total stretch, measured in a length of 8 inches, from 20 to 30 per cent.; and a reduction of the area of the fractured section, from 40 to 55 per cent.; the ductility having the lowest values corresponding to highest tensile strength; for, as tensile

strength increases, as a general rule, ductility decreases, and *vice versa*.

For rivets, it is customary to use soft, ductile steel, tensile strength below 55,000 pounds, and this is desirable if the rivets have to be set by hand; but with suitable appliances for riveting, the strongest connection will be made by using a strong metal of high quality, as heretofore defined for the body of the structure, and workmen who may be required to cut out these rivets can always bear testimony to the faithful grip they so tenaciously hold. High tension structural steel, say of 80,000 pounds, or over, in tensile strength, has decided advantages when used under compressive strains alone, but there is a natural aversion to trusting it too far, when subjected to mixed or impactive stresses, possibly for the same reason that we formerly dreaded high pressure steam or electric currents of high voltage, which are freely tolerated now.

The evil effects of phosphorus are believed to be intensified when associated with high carbon, and extreme low phosphorus basic steel is necessarily low in carbon as it leaves the furnace, as the carbon must be quite low before the phosphorus parts company with the metal to mate with the slag.

Moreover, steel, whether of high or low tensile strength, has a nearly uniform modulus of elasticity; that is, all grades extend, or compress, or deflect alike under similar loads, below the elastic limit of the material. Therefore, high tensile strength is not always available, as the engineer has to consider stiffness and rigidity as prime factors in the satisfactory use and endurance of structures. There are some reasons to believe that very pure steel is peculiarly susceptible to corrosion, and that some immunity is given by the presence of some of the usual constituents. The difference, if any, in resistance to corrosion, between ordinary commercial grades, is not very distinct, and could only be demonstrated by an extended series of experiments. The addition of a considerable proportion of nickel reduces the liability to corrosion.

Soft steel withstands high temperature in the reheating

furnace better than the harder grades. Much damage may be done to a medium grade of steel by a degree of heat, especially if unduly prolonged, that would not markedly affect very soft steel.

Steel is susceptible of a profound change in its physical properties when subjected to the proper action of heat, and the method of cooling, or of so-called annealing or tempering processes.

This property is notably exemplified in the annealing of steel castings. The metal of the untreated casting has a coarse, open grain, possessing little ductility, and is comparatively brittle, although immeasurably superior to the very best cast iron. By raising the temperature of the unannealed casting to a red heat, and allowing it to cool, without any other manipulation, the coarse open grain is changed to a fine close one, resembling tool steel, as we ordinarily have it in the bar. The strength or ductility of the metal may be greatly augmented, and the texture may be made soft or hard, according to the rapidity with which the heated mass is cooled, modified, of course, by the content of carbon, which determines the ability to harden. This change is further modified by cooling in fluids of various temperatures as exemplified in the old and well-known process of oil-tempering, now practised on a large scale on ordnance and armor, and important parts of machinery and structures, where exceptional resistance is requisite. Even soft steel, as low as 0·1 per cent. carbon, will vary in tensile strength fully 5 per cent., according to the temperature at which it is finished.

An experienced authority says that every piece of steel bears in its structure a record of the last temperature to which it was subjected.

The production and manipulation of steel requires a higher degree of skill and intelligence to obtain satisfactory results than was formerly devoted to wrought iron. The condition of fusion renders the metal liable to absorb or retain injurious substances, which does not so freely occur at the lower temperature at which wrought iron is produced. A fair judgment can be expressed by an expe-

rienced eye, upon the appearance of a fractured specimen of wrought iron. No similar test can be applied to steel. First-class concerns, now, are governed by analysis of both raw and finished materials, and results checked by constant testing in the physical laboratory.

Neglect of this vigilance would result in the production of questionable metal, possibly in havoc or destruction. The faithful adherence to sound and thoroughly approved methods will result in material to which men may commit their reputations and their lives, and insure a metal which will verify the old motto, and be "true as steel."

Given a steel on which this intelligent care has been bestowed during its production and final manipulation, fashioned into a structure which embodies the carefully digested study of the designer, the product of the science and practical art of generations, and we behold a creation, the highest type of combined strength and elegance, whether it be the ocean flyer that defies the tempest, the bridge that does not quiver under the express train, or the lofty building that bears its ponderous burden, and faces the gale without distress.

THE MODERN OFFICE BUILDING.[1]

By Barr Ferree.

A lecture delivered before the Franklin Institute, November 15, 1895.

PART I.

The largest and most costly structures now being built are the modern office buildings of America.[2] Some few monumental undertakings of foreign governments may, indeed, exceed them in price, as many a smaller building

[1] In undertaking to treat so large a subject as the modern office building in all its phases, economic, structural and æsthetic, within the scope of a single article, it is obvious that only the most summary review can be attempted. In order that the reader, who may be desirous of pursuing the subject further, may at once place his hand upon the latest literature on the subject, references have been made, in the foot-notes, to recent articles and papers in the professional journals, in which fuller accounts of the points

exceeds them in monumental effect; but in no other group of structures are the expenditures so large, the responsibility of architects so great, or the opportunity of profit to the designer so handsome. For the architect, the labor involved in the erection of an office building is very large. He requires a numerous corps of assistants, whose whole time for many weeks will be needed to prepare the working drawings; he will require an engineer to design the foundations and the frame of steel on which the building is to be carried, who, in his turn, will need his own assistants; he will require careful superintendents, and every step of the work will call for constant watching; he must, moreover, be familiar with many sciences and with much detail that a few years ago had no part in an architect's knowledge.[3] His building must be heated and lighted; it must be supplied with elevators and with elaborate electric and sanitary systems. Every new device must be watched and tested, in order that the latest office building may, with the utmost literalness, be "modern."

But the responsibility of the architect scarcely equals that of the investor who puts his money into these great enterprises. I am speaking of office buildings of the largest size, for many smaller ones are erected, as convenient and as well equipped as the larger, perhaps, but which are not typical examples of this class of buildings. The modern office building is an exceedingly costly structure. The land on which it is erected is, as likely as not, in the center of the city's business district, where rents are high and land invaluable. The method of construction is costly; for while the steel skeleton system of construction, which is now

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under discussion may be found. The foot-notes appended to this paper are not, therefore, offered as authorities for the statements contained in it, but as keys to more extended studies of the subjects. The references are not, in any case, to be taken in a bibliographic sense, nor is any pretence made to do more than cover the latest American literature in a most summary fashion.

[2] For a summary of the cost of some office buildings and others, see F. E. Kidder: "What Buildings Cost per Cubic Foot," *American Architect*, February 17, 1894.

[3] See an interesting paper on "The Difficulties of Modern Architecture," *Architectural Record*, Vol. 1, p. 137, by Prof. A. D. F. Hamlin.

almost universally employed in these buildings, considerably increases the interior areas, owing to the thin walls that can be built in this way, the actual expenditure, save in buildings of great height, is more than under the old system of solid walls, carrying the floor and roof loads in addition to their own weight.

An interesting case in point is the American Surety Building, in New York, which occupies a site about 85 feet square, that cost in the neighborhood of $1,500,000, or at the rate of about $8,000,000 per acre. The building itself cost at least $1,500,000 more, so that the total investment considerably exceeds $3,000,000. It has 21 stories, and is 300 feet high. Under the old system of solid walls, this structure would not have been a profitable investment, since the thickness of its walls at the ground floor would have been nearly 7 feet. As actually built, the thickness of the walls is 3 feet at the ground, and the internal area 5,000 square feet of floor space on a lot of 7250 square feet.

It is obvious that buildings so costly as this can be no ordinary structures. They represent a lavish expenditure, but a lavishness that is expended on business principles and in a business way. The office building is a commercial venture, undertaken, not with the object of beautifying the city, or of satisfying the æsthetic ideas of its owners, but as a commercial investment, in which the rents shall return a net profit that represents the income from the money it has cost. The building may be ornamental; that is to say, its ornamental aspect may be a necessary part of the scheme; but if so, it is not an æsthetic effect that is sought, but an attractive exterior and a well-planned interior, that will bring tenants and excite favorable comment from the passer-by. The artist would doubtless contend that such commercial conditions would mean the extinction of art in buildings of this description, and he would be right, in so far as many commercial buildings are totally without artistic interest, though there has been no limit to the expenditure. But though the modern office building is as yet scarcely more than in its infancy, the commercial value of a really artistic building has already been recognised by in-

vestors. And so, though the public at large—and the architects, too—scarcely understand the possibility of artistic expression in these buildings, of any two, one of good design and one of bad, the former will prove the most attractive to the better class of tenants, and, therefore, the more remunerative.

But while this is true, and the artistic side of the office building is receiving an attention not heretofore given to it, it is a purely commercial enterprise, undertaken for profit, without, save in the way that has just been pointed out, any artistic significance. And so, being a commercial building, and this being a commercial age, it is not inappropriate that our cities should be dominated by their commercial edifices, beside which the church towers are insignificant; for the office building is as typical of the life of our age as the sumptuous baths and great palaces were typical of the life of imperial Rome, or the cathedrals of the religious fervor of the Middle Ages. They have, therefore, an economic significance which no other structures of our time possess, which makes them modern in a real sense of the word.

The modern office building, as it is considered in this paper, is a purely American product. It has arisen from the concentration of the business centers of our American cities upon areas of relatively small dimensions. Its greatest development has been in Chicago, where the business center is a very small part of the city's area, and is confined within the limits bounded by Lake Michigan, the Chicago River, and the railroads centering in the city.[1] In New York, the business area is spread over a larger extent of ground, but the situation of the city on a narrow island, and the concentration of business upon the lowest extremity of this strip of land, has hastened the development of the office building in it as well as in the metropolis of the West, and for very similar reasons.

Obviously, when the pressure of population has used up the ground area, the need for accommodation becomes so

[1] "The Railway Problem of Chicago." Report of a Committee of the Western Society of Engineers. *Journal of the Association of Engineering Societies*, 11, p. 223.

great that vertical expansion is forced upon real estate owners, whether they will or no. In foreign lands such vertical expansion is hindered by vested rights, or privileges of light and air, which hem in building operations in England in a way quite unknown in America;[5] or by rigid building laws, which forbid structures of extraordinary height, or any above the average height upon streets of certain width. Building has proceeded upon freer lines in American cities, where it has seemed more suited to their development to induce a free erection of buildings than to hinder municipal growth by introducing elements of restriction. But already a reaction has set in, and many cities, Chicago among the number, have made regulations limiting the heights of buildings, and forbidding more than a certain height upon lots of a given size, or upon streets of a certain width.[6]

How far these restrictions may be needed is problematical.[7] It has been urged that the continued erection of

[5] Banister Fletcher: "Light and Air," second edition, London, 1886.

[6] The situation in regard to limiting the height of high office buildings may be briefly summed up in this way: Every one would be glad to own a profitable high building, or any number of them. But real estate owners are divided as to their multiplication; those who have them already do not wish more, for that might mean a diminution of their profits; those who have none at all, and in this class must be included the larger number of property owners, do not want more, for that would mean a continued concentration of the business center upon one spot. The architects do not want more of them, for while they are exceedingly profitable pieces of design, the larger part of that profession have shown themselves incapable of designing them, and they wish, therefore, to get rid of the problem. The general public is opposed to them, because of the thoughtless agitation in the press and the technical journals against them, by people who do not understand their value. The newspapers of New York would loudly advocate any legislation that would render the erection of more high buildings in that city impossible, because they have high buildings of their own, and do not wish more competition than they already are subjected to. On the other hand, the high buildings have enormously increased the value of real estate in certain parts of crowded cities, and they have unquestionably given many notable structures to our cities, which, if not always joys to look at, are among the most important we possess. They have, moreover, an economic value in commercial life that has had a great influence on the methods of modern business.

[7] For a well-balanced estimate of the value of high buildings and their dangerous qualities, see D. Adler: "Tall Office Buildings, Past and Future," *Engineering Magazine*, September, 1892.

high buildings will make our streets veritable cañons between great walls of offices, which will not only darken them, but render the lower offices unprofitable for want of light. That a very narrow street between very high buildings is a thing to be avoided is unquestionably true; but the objections to these buildings, both on this and other grounds, have been greatly exaggerated. That they are sources of disease in preventing the free circulation of the air is as yet only a matter of opinion, while it is a fact of common observation that the wind never blows so swiftly and so strongly as around high buildings; and it is probably true that their continued multiplication will lessen the renting value of the lower floors. But commercial buildings are commercial enterprises, and the moment they become sources of danger, or any considerable part of them unrentable, at that time will come that natural check to their erection which must follow from the conditions under which they are erected.

The modern office building houses an immense population. Two or three thousand people in a single one is no exaggeration. Were they built without regard to the utmost advance of sanitary and constructive science, there might be just ground for alarm at their increase. But, as a matter of fact, no buildings of our time are erected with greater care, or with a more thoughtful regard for the convenience and safety of the people who pass their working days within them. Every possible improvement is pressed into service, and the latest building, if it has been well done, is a distinct advance on its predecessor. There is still much to be accomplished; the problem of ventilation is not yet solved; perhaps the manner of heating requires further development; but these imperfections are as characteristic of lesser buildings as of the greater; they are a part of the faults of modern architecture as a whole, and are only considered in relation to the office building because of its size and importance.

It is no small achievement to erect a single structure that will contain more people than the population of a good-sized town. Countless contrivances for the safety and con-

venience of human life must be employed in such buildings before they can properly answer to the needs of modern commercial life. They must be well lighted, conveniently planned, amply equipped with elevators, and with the latest devices in heating, lighting, plumbing and electricity. For their proper working a vast mechanical plant is required, including boilers and steam engines, electric light apparatus, ventilating apparatus, a system of sewage disposal, and often, if the soil is full of water, an elaborate system of pumps whereby the foundations and the cellars may be kept clean and wholesome.[8] For the convenience of the tenants an army of attendants, janitors, elevator boys, firemen, engineers, electric experts and the like, is needed. There must be no break in the intricate system which keeps these buildings alive, night and day, and often without cessation the year round. Many of the factors needed to render them serviceable are invisible to the public, as well as to those who daily use them, but they form an essential part of the building, and help to make them among the most remarkable structures built by human hands, as they are among the most complex.

And not only is there an infinity of necessary devices, but the complete and modern office building includes a host of conveniences that are not, strictly speaking, a part of its architecture. It will contain, in addition to its offices, many comforts and luxuries that make it, in a sense, independent of every other building. It will have boot-blacking stands, a barber-shop, baths, restaurants, cafés, cigar-stands, news-stands, minor shops and booths, and perhaps a club, whose membership will be largely composed of the tenants. When to these are added the very varied businesses that find shelter within it, it is apparent how notable these buildings are in their contents as well as in their size and cost.

Two great factors render the modern office building capable of erection—the elevator and the skeleton system of construction. The utility of the latter in effecting an

[8] For detailed descriptions of plumbing, heating and other mechanical devices in large office buildings in representative instances, see "American Steam and Hot Water Heating Practice," New York, 1895.

economy of renting area has already been alluded to, and the details of the system will presently be considered at length. The elevator is, of course, the chief economic device that renders the lofty buildings accessible to the public, as without it the upper floors would be inaccessible. The elevator has made the office building a commercial success, and, conversely, the demand for swift, safe and economical service has had its influence upon the development of that device, and enormously increased the elevator industry. Were any one feature to be singled out as having contributed the most to the development of the office building, that would, without question, be the elevator.

For we can erect office buildings without steel construction, as will be seen in the sequel, though not so economically. But, in a sense, we would build better; for, where five or more feet of the ground floor would be needed for a self-sustaining and supporting wall of masonry construction, there would be an end to the present custom of erecting office buildings upon narrow sites. That the practice of erecting narrow office buildings is much overdone, especially in New York, cannot be questioned, and, in time, that city will certainly show block after block of office buildings whose narrow fronts can never, from their limitations of width, have the artistic value of broad and spacious façades. Nor is the misfortune simply one of æsthetic effect. It costs more to build ten office buildings than one covering the same area, and the total operating expenses of such a series would be considerably in excess of the operating expenses of a single building. Good economy would discourage the increase of small office buildings and offer every inducement to the building of large ones. A case in point is the Monadnock Block in Chicago, in which four buildings, owned by different parties, though built in sections of two each, at different times, form one continuous interior under the same management, and practically one vast business building. A similar union of owners in building enterprises would, unquestionably, produce most satisfactory returns on the investment, which could not but be greater than the return from a number of single buildings.

In giving architectural expression to so complicated a structure as the modern office building, the architect needs to keep in view all these conditions and limitations. In a sense, he is not a free agent, in so far as he is unable to arrange his façades in accordance with the dictates of his own taste. He can waste no room in massing his front, in making a recess here, or a projection there, no matter what the artistic effect might be of doing so. On one hand stands the owner, protesting he must have every possible inch of the area for renting purposes; on the other, is the municipal building law, which forbids extension beyond the building line. All the architect can do is to keep strictly upon that line, and this, as we shall see, the skeleton system enables him to do economically and well.

Not the least of the economical advantages of the skeleton system is the speed with which it enables buildings to be erected. An office building of the largest size can now be built, with steel, in a space of time that is positively astonishing. Not only is the system a rapid one, but the lower portions of a building can be practically completed, and tenants in possession, before the upper parts are finished. As in each story, in the pure veneer type, the walls are carried on the girders at that point, it is possible to fill in any story without reference to what is above or below, and it has sometimes happened that the first floors of a high building were the last to be given their completed form. The question of speed in erection is a most important consideration in these costly structures, and this system seems to more than satisfy any requirements that may be insisted on in this particular.[9]

Part II.

The structure of a foundation[10] is determined by what it is to carry. While we build our buildings up from the foundations, their engineering begins with a consideration

[9] Thirteen and one-half stories of the iron work of the Fisher Building, Chicago, were put in place in 14 days. This is an 18-story building, 70 x 100 feet.

[10] For general treatment of questions relating to foundations, see J. O. Baker: "A Treatise on Masonry Foundations," eighth edition, New York, 1895.

of the loads to which they are to be subjected—the strains and stresses. The weight of the building being calculated and fixed, the next step—though the first in actual construction—is the determination of the form of the foundations.

The nature of the foundation of a high building depends on the weights of the structure, the nature of the soil, the nature of the adjoining edifices and their foundations, and economy or cost. Economy, which usually comes first in mechanical operations, is the least important of the conditions, since, as the object of a foundation is to carry its building, no economical arrangement can be employed that does not recognise this fact. The adaptability of the building to its foundation need not be considered, since any sort of a steel frame can, in practice, be applied to any sort of a foundation.

The foundation will, to a great extent, depend upon the soil upon which it is built. The most desirable are those built directly upon rock; but modern engineering is independent of the nature of the soil, though whether this be rock, clay, sand or gravel will largely determine what sort of foundation is to be laid. For present purposes this aspect of the question may be neglected, and the foundations considered with reference to their structure only.

The foundations of high buildings may be divided broadly into two classes: continuous and isolated.

Continuous foundations, as their name implies, are solid, uninterrupted walls, carried wholly or in part around the building. They may rest (1) on earth or rock; (2) on piles; or (3) on beds of concrete.

A continuous foundation on earth simply requires that the soil shall be of sufficient density to support the weight that will be applied to it through the foundations. Rock requires to be cut away at the surface, and any imperfect or decaying strata got rid of.

W. M. Patton: "Practical Treatise on Foundations," New York, 1892. W. R. Hutton: "Foundations of High Buildings," *Engineering Record*, September 23, 1893, also in *American Architect*, November 18, 1893. W. H. Burr: "The Engineering of Architectural and Building Construction," *Engineering Record*, January 6, 1894, *seq.*

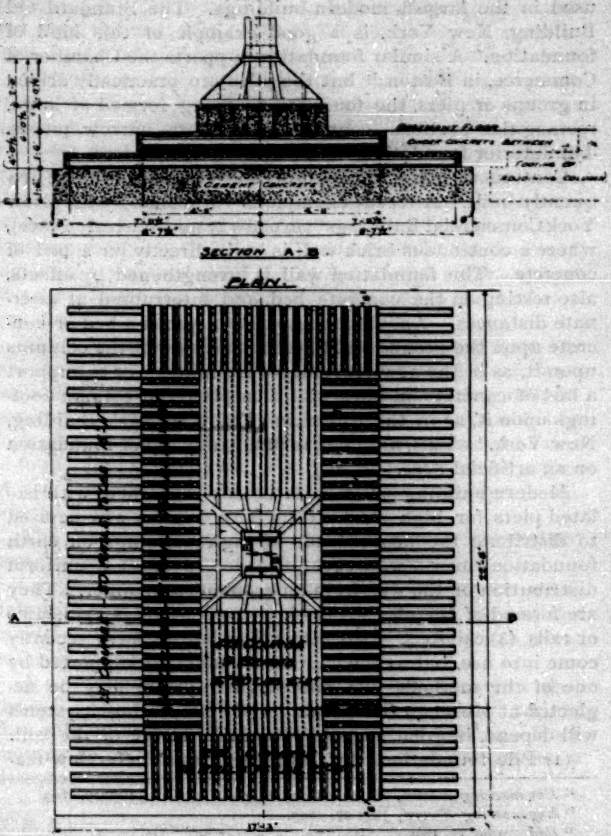
A continuous foundation on piles is a type not much used in the largest modern buildings. The Standard Oil Building, New York, is a good example of this kind of foundation. A similar foundation supports the Chamber of Commerce, in Boston;[11] but the piles are practically driven in groups or piers, the foundations being formed of large, rectangular sections, connected by short, narrow pieces. The interior foundations rest on true isolated piers.

Continuous foundations on beds of concrete are not frequently built. A recent example is furnished by the New York Commercial Buildings[12] (Broadway and Waverly Place), where a continuous brick wall is built directly on a bed of concrete. The foundation wall is strengthened by offsets, also resting on the concrete bed, and interrupted at alternate distances. Another method is to spread a bed of concrete upon the ground and to erect the bases of the columns upon it, as in the new Havemeyer Building;[13] or to support a bed of concrete on piles, and then place the column footings upon it, as in the American Tract Society's Building, New York.[14] This, however, is practically a pier foundation on an artificial base.

Modern building practice is chiefly concerned with isolated piers for high structures. This system was devised to distribute the heavy loads of high buildings on earth foundations over a wide area, in order to effect a uniform distribution of the weight in an economical manner. They are formed of (1) piles, (2) brick or concrete piers, (3) beams or rails, (4) caissons. Cantilever foundations have recently come into use, but as the cantilevers must be supported by one of the methods just named, that system may be neglected at present. The selection of one of these systems will depend, in great measure, upon the nature of the soil.

(1) Pile foundations for high buildings[15] offer few fea-

[11] *Engineering Record*, May 7, 1892; *Inland Architect*, January, 1893.
[12] *Engineering Record*, July 27, 1895.
[13] *Ibid.*, June 15, 1895.
[14] *Ibid.*, December 15, 1894.
[15] A. M. Wellington (editor): "Piles and Pile Driving," New York, 1893. Wm. Sooysmith: "Pile Foundations in Chicago," *American Architect*, August 5, 1893. "Notes on Pile Foundations in Chicago," *Engineering News*, September 21, 1893.



Section and plan of a Chicago steel rail and beam foundation, as used in "The Fair" Building, Chicago.

tures in construction that are not familiar to engineers. Their long-continued use renders them, in many respects, highly desirable foundations where the rock-bed cannot be reached, and where there is a hard stratum to which they can be driven. Piles were almost universally employed prior to the introduction of the isolated pier system, but were somewhat neglected after steel rails began to be used. Recently their employment has been revived to a considerable extent, and in Chicago they have, in some instances, taken the place of the distinctive rail foundations. In 1889 piles were employed for the Wisconsin Central Depot, and, subsequently, in the Schiller Theatre, the Newberry Library, and the Stock Exchange in Chicago. Special pains were taken with the foundations of the Newberry Library, which were subjected to an elaborate series of tests.[16] Good practice requires that the piles should be driven to rock or to hard-pan. A proper penetration of a hard stratum is often sufficient, if the rock is too low down, for the piles may be held in place by frictional resistance without actually resting on a solid substance. The piles should be cut off below water-level at a sufficient depth to permit any timber grillage erected on them to be permanently under water.

(2) Brick or concrete piers are seldom employed in the best and latest construction, on account of their poor economy of space. The Drexel Building, Philadelphia,[17] is supported by foundation piers of hard brick in concrete, connected by inverted arches whose heads are embedded in the concrete on which the footings rest. Some of the large piers of this foundation are of granite.

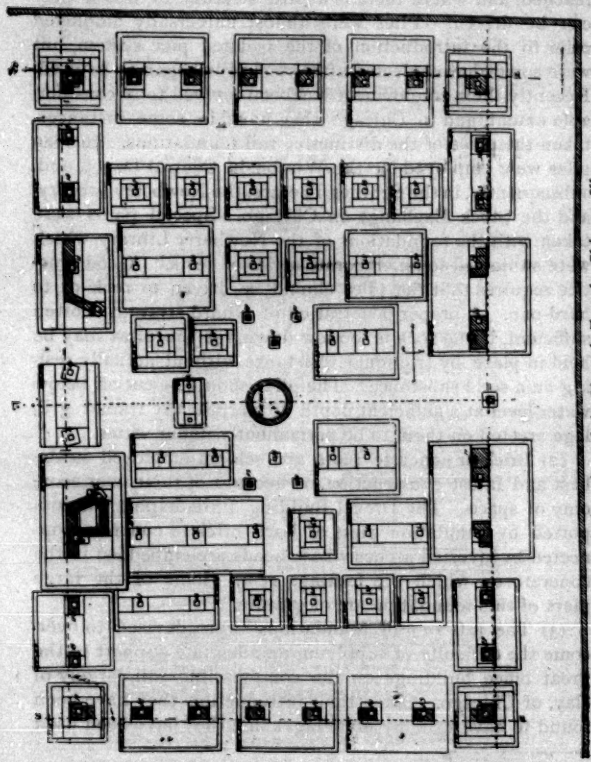
(3) The raft or rail foundations[18] were devised to overcome the difficulty of supplying an adequate support to the great office buildings on the compressible soil, largely of clay, of Chicago. Since their introduction they have been found to have so many advantages that they have been used

[16] *Engineering News*, July 6, 1893.

[17] *Engineering Record*, May 4, 1889, *seq.*

[18] C. T. Purdy: "Steel Foundations," *Engineering News*, August 8, 1891. W. L. B Jenney: "Chicago Construction," *Engineering Record*, November 14, 1891; also in *Inland Architect*, November, 1891.

elsewhere. At first they consisted of old rails, then of I-beams for the upper course or courses; at present, I-beams especially manufactured for this purpose are employed.

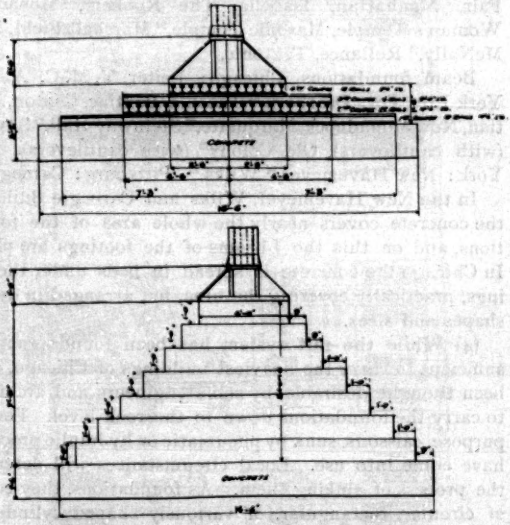


Foundation piers of the Masonic Temple, Chicago, Ill.

This type of foundation is relatively simple; a layer of concrete supports the layers of I-beams, all encased in concrete to protect the steel, and supporting a casting to which is

applied the base of the column of the frame. It has many advantages.

It causes a great saving of space. A steel foundation, whose height between its bed of concrete and the bottom of the casting on which the column rests is 1 foot 8 inches, will be equivalent to a masonry foundation 7 feet high, when the latter is stepped out to transmit the load over the same area. This saving of space amounts to the height of



Comparative section of steel and stone foundation.

a basement, which is an item of more moment in Chicago than in New York, because the soil of Chicago does not offer opportunity for basements and sub-basements with ordinary construction. At the same time, the steel foundation is much lighter in weight than the corresponding foundation of stone, and this permits the addition of an extra story to the building without adding to the load on the soil. Steel foundations are more costly in themselves

than stone ones, but their great economy in space, in weight, and in the time necessary for their erection, more than compensates for their increased price. To the other advantages must be added the final one that masonry foundations are often unfortunate for sidewalls, because they cannot be properly stepped out on both sides without encroaching on the adjacent lot.

Examples.[19]—Beam and rail footings, Chicago: The Fair, Manhattan, Isabella, The Rookery, Monadnock, Woman's Temple, Masonic Temple,[20] Marshall Field, Rand-McNally,[21] Reliance, Teutonic.

Beam foundations, Chicago: Leiter, Y. M. C. A., New York Life, Fort Dearborn,[22] Tacoma, Pontiac, Caxton, Venetian, New Monadnock, Marquette,[23] Steinway Hall,[24] Atwood[25] (with cantilevers), Old Colony[26] (with cantilevers). New York: New Havemeyer,[34] Wilks.[35] Pittsburg: Carnegie.[36]

In the New Havemeyer, Wilks and Carnegie Buildings, the concrete covers nearly the whole area of the foundations, and on this the I-beams of the footings are placed. In Chicago the concrete is spread in beds under the footings, practically covering the area, but arranged in definite shapes and sizes.

(4) While the raft system has been found practically sufficient to carry the heaviest buildings of Chicago, it has been thought desirable, by some engineers and architects, to carry the foundations down to the rock level. For this purpose, caissons, sunk by pneumatic or hydraulic processes, have come into use. Local circumstances will determine the process of sinking them. As foundations, they consist of circular, rectangular, or variously shaped cylinders or enclosures of sheet metal, filled with concrete and brick.

[19] No attempt has been made in this, or similar lists, to compile a full list of examples; only a few well-known buildings are named in each class.

[20] *Engineering Record*, January 21, 1893, *seq.*

[21] *Ibid.*, December 12, 1891, *seq.*

[22] *Engineering News*, October 17, 1895.

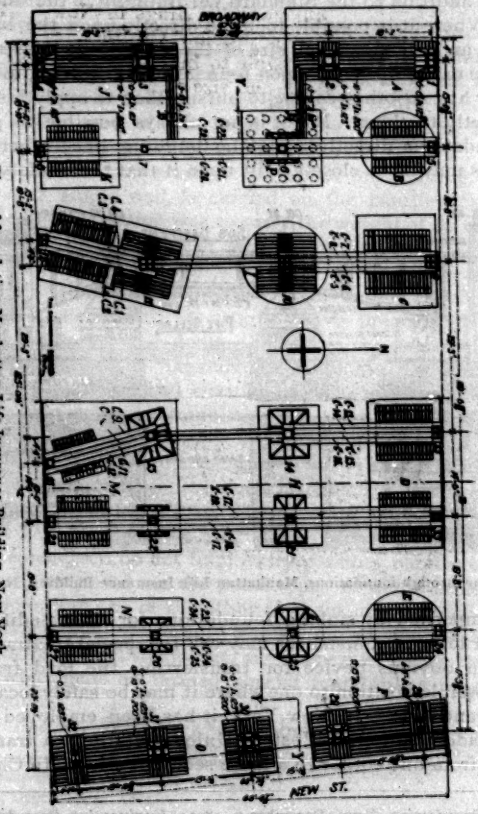
[23] *Ibid.*, December 21, 1893.

[24] *Engineering Record*, June 15, 1895.

[25] *Ibid.*, June 1, 1895.

[26] *Engineering News*, January 11, 1894.

These are covered with a proper cap, to which is applied the casting for the base of the columns. They are, in fact,

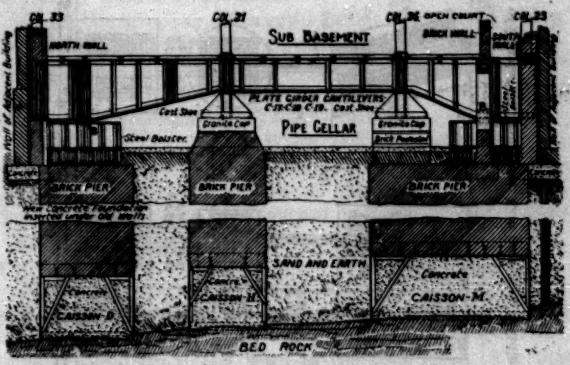


Plan of foundation Manhattan Life Insurance Building, New York.

simple columns or piers of masonry, which carry the weight of the building to the rock below. Examples of this type

of foundation are found in the Manhattan,[27] the American Surety[28] and Johnston[29] Buildings in New York, and in the new addition to the Standard Oil Building in the same city.

Where it is possible to build directly upon the building line, and the shape and size of the site permit the structure to be carried directly upon foundations so placed, the engineer has no other course to pursue than to apply his frame directly to them. But it is not always possible to get the foundations directly upon the building line; other structures may be so closely built upon it that their safety would



Section through foundations, Manhattan Life Insurance Building, New York.

be imperiled by sinking foundations for a new edifice; or other local circumstances may call for special treatment.

An obvious device for transferring the load from an impossible position to one where it may be safely located, is the cantilever. In New York, it has been employed in the new addition to the Western Union Building, to transfer a load from one corner to a more secure footing. In Chicago,

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[27] *Engineering News*, December 7, 1893; *Engineering Record*, January 20, 1894.

[28] *Engineering Record*, July 14, 1894; June 6, 1895.

[29] *Ibid.*, July 13, 1895.

it has been used in the Manhattan and the Rand-McNally[30] Buildings, because heavy machinery in the basements of the adjoining structures could not be moved to permit the introduction of new party-footings. More recent examples in the same city are supplied by the Atwood[31] and the Old Colony Buildings.[32] In the former the north and west walls are carried on cantilevers; in the latter, the south wall. In New York a part of one wall of the American Tract Society's Building is carried on cantilevers.[33]

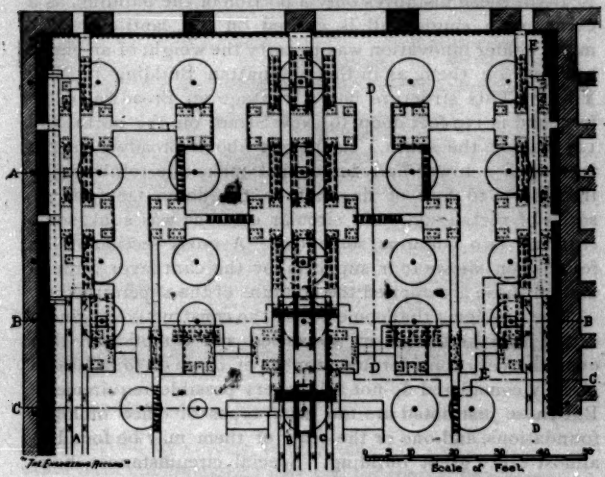
In all these instances only a portion of the building, as a corner or a single wall, is carried on the cantilevers. A much bolder innovation was to carry the weight of an entire building on them, as in the Manhattan Building in New York.[34] This structure has a frontage on Broadway of 67 feet, and is 119 feet deep to New Street on the north, and 125 feet on the south. Its height above Broadway is 242 feet, with a tower and dome, that make the total height, from curb to foot of flagstaff on the dome, 348 feet. A series of rectangular and circular caissons was sunk, some carrying two columns, some one. A cross section of the foundation shows four supports for the cantilever girders, and on these are applied the columns of the superstructure.

The problems that come before the constructive engineer in the high buildings are so varied and complicated that even the very considerable number of types of foundations already considered do not fulfil every possible requirement. But those just noted are the usual types of office building foundations, and one or the other of them may be found in almost every great building. Special circumstances, however, call for special treatment, and some interesting examples of what may be termed special foundations may be briefly noted.

Cable Building, New York.[35]—To obviate the intense vibra-

[30] *Engineering Record*, December 12, 1891, *seq.*
[31] *Engineering News*, October 17, 1895.
[32] *Ibid.*, December 21, 1894.
[33] *Engineering Record*, December 15, 1894.
[34] *Ibid*, January 20, 1894.
[35] *Engineering News*, October 5, 1893; *Engineering Record*, September 3, 1892.

tions of the cable machinery, a system of double foundations was devised. The inner columns of the superstructure rest on steel foundations of the usual type, applied to concrete enclosed within steel cylinders 6 feet deep and from 4 to 12 feet in diameter. A heavy layer of concrete covers the ground around these cylinders, and serves as a foundation for the machinery. The outer columns were built within the enclosing walls, on grillages formed of a single layer of steel beams, 24 feet above the beginning of the walls.



Portion of foundation plan of Cable Building, New York.

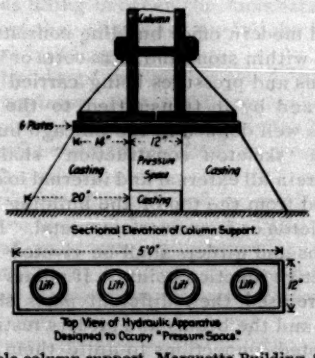
Marquette Building, Chicago.[38]—The foundations of the west wall of this building were designed to carry an additional structure not yet built. The present load is, therefore, unequal and different from the final load. A special device was introduced to meet this condition in the column footing applied to the usual I-beam and concrete base, consisting of a cast steel shoe resting on six plates, which, in

[38] *Engineering News*, October 17, 1895.

turn, rest on two large iron castings, with a space between, in which is an hydraulic apparatus with four lifts. Should the wall give evidence of settling, the pressure can be applied and the thin plates between the castings removed, or additional ones inserted, as may be required.

New Havemeyer Building, New York[37] (on site of old Herald Building).—A similar device of hydraulic lifts will be applied to this building, to provide for a possible heavy adjoining building in the future.

Fisher Building, Chicago.[38]—In this structure an attempt was made to provide a device which would squeeze the



Adjustable column support, Marquette Building, Chicago.

water out of the ground before the building was placed on it. In this way it was hoped to form a solid base which would overcome the settlement which follows from the squeezing of the water by the weight of a heavy building, and at the same time obtain a resisting strata for the piles, sufficiently firm to render driving to hard pan unnecessary. Piles 25 to 27 feet in length were driven close together under each column. About 6 inches of concrete was packed close below the tops of the piles, and 18 inches placed on

[37] *Engineering Record*, June 15, 1895.

[38] *Engineering News*, October 17, 1895; *Engineering Record*, October 19, 1895.

top. On this was built a steel beam and concrete foundation, with a shoe of the usual form. This system has been employed by the same architects and engineers in the Mabley Building, in Detroit.

Old Colony Building, Chicago.[39]—This building offers a good type of a combination of a direct and cantilever foundation. The north wall is carried on cantilevers; the others are supported by columns that rest directly on concrete and beam foundations of the usual type. The distribution of the load was such that six columns were included on the single large concrete base supporting the footings of the cantilevers.

The typical modern office building consists of a cage of steel enclosed within stone and terra-cotta or brick walls, the weights, strains and pressures being carried wholly on the metal frame, and by it transmitted to the foundations.[40] This system is well defined in the Chicago building law:

"The term 'skeleton construction' shall apply to all buildings wherein all external and internal loads and strains are transmitted from the top of the building to the foundations by a skeleton or framework of metal. In such framework the beams and girders shall be riveted to each other at their respective junction points. If pillars made of rolled iron or steel are used, their different parts shall be riveted to each other, and the beams and girders resting upon them shall have riveted connections to unite them with the pil-

[39] *Engineering News*, December 21, 1893.

[40] W. H. Birkmire: "Skeleton Construction in Buildings," second edition. New York, 1894. J. K. Freitag: "Architectural Engineering," New York, 1895. C. T. Purdy: "The Steel Skeleton Type of High Buildings," *Engineering News*, December 5th, *seq.* C. T. Purdy: "The Use of Steel in Large Buildings," *Journal of the Association of Engineering Societies*, 14, p. 182, reprinted in *Engineering Record*, February 16, 1895, *seq.* C. T. Purdy: "Steel and Iron Construction in Buildings," *Inland Architect*, June, 1892. "High Buildings of Steel Construction," *Engineering News* December 27, 1894. P. B. Wight: "Recent Fire-Proof Building in Chicago," *Inland Architect*, February, 1885, March-June, 1892. D. Adler: "Tall Buildings," *Inland Architect*, June, 1891. C. H. Blackall: "Specification for Structural Steel Work," *American Architect* December 22, 1894. "New Office Buildings in Chicago," *Engineering News*, February 16, 1893. "Recent Chicago Tall Buildings," *ibid.*, October 17,

lars. * * * If buildings are made fireproof entirely, and have skeleton construction so designed that their enclosing walls do not carry the weight of floors or roof, then their walls may be reduced in thickness one-third from the thicknesses hereinafter provided for walls of buildings of the different classes, excepting only that no wall shall be less than 12 inches in thickness; and provided also, that wherever the weight of such walls rests upon beams or pillars, such beams or pillars must be strong enough in each story to carry the weight of the wall resting upon them without reliance upon the walls below them. But if walls of hollow tiles are used as filling between the members of the skeleton construction, they shall be of the full thickness specified for non-skeleton buildings."

All office buildings are not of this type, and practice varies among engineers to a much greater extent than is generally supposed. Some very large office buildings have been built of solid walls throughout; in others some or all of the walls are self-sustaining; in others, again, such self-sustaining walls are strengthened by steel girders, or the lower part of the wall will be self-sustaining and the upper parts be carried on girders, thus reducing the space and weight of the lower walls; in others, finally, and this is the typical skeleton construction, the walls are carried on the frame at each story.

Solid walls, without steel columns.—Monadnock, old part;

1895. W. J. Fryer: "Skeleton Construction," *Architectural Record*, 1, 228. L. De C. Berg: "Iron Construction in New York City," *ibid.*, 1, 448. G. Hill: "Some Practical Limiting Conditions in the Design of the Modern Office Building," *ibid.*, 2, 445.

For detailed studies of the construction of notable office buildings consult: "Drexel Building, Philadelphia," *Engineering Record*, May 4, 1889, *seq.* "World Building, New York," *ibid.*, November 1, 1890, *seq.* "Rand-McNally Building, Chicago," *ibid.*, December 12, 1891, *seq.* "Boston Chamber of Commerce," *ibid.*, May 7, 1892, *seq.* "Masonic Temple, Chicago," *ibid.*, January 21, 1893, *seq.* "Old Colony Building, Chicago," *Engineering News*, December 21, 1893. "Manhattan Life Insurance Building, New York," *ibid.*, December 7, 1893. *Engineering Record*, January 20, 1894, *seq.* "New Havemeyer Building, New York," *Engineering Record*, June 15, 1894. "American Tract Society's Building, New York," *ibid.*, December 15, 1894. "Wilks Building, New York," *ibid.*, June 1, 1895.

Auditorium; The Rookery; Woman's Temple; Marshall Field; Owings Building—all in Chicago.

Mixed walls, part solid, part veneer.—The new Monadnock in Chicago consists of two parts, exactly alike externally. One, the Katahdin Building, has its exterior walls supported by masonry piers, 7 feet thick at the level of the first floor; the other part, the Wachusetts Building, is of the pure skeleton type.[41]

The Mail and Express Building, New York, is an L-shaped structure, with an exceedingly narrow arm reaching out to Broadway. All the walls are self-sustaining, including the fronts on Broadway and Fulton Street, except the side walls of the narrow arm, whose steel construction was necessitated by the fact that solid walls would have left no practical renting area between them.

In the Manhattan Building, New York, the walls are wholly, or in part, of the skeleton type, except the Broadway front. "The first story on Broadway, up to the springing of the arches of the windows, is of granite, the full thickness of the wall. Thence up to the first story cornice the thickness of the stone is equal to the reveals of the windows directly over the openings, the piers running up solid to the cornice, and being backed up over the windows with brickwork to the full thickness. Each stone is securely anchored and tied to the brickwork, and a thorough and efficient bond is maintained throughout the entire brickwork once in every five courses, and every course of brick is solidly filled in with cement. The intervening walls between piers on the north and south lines are supported on arches extending from pier to pier."[42]

Self-sustaining walls, carrying themselves only, as in the Auditorium Annex and the Masonic Temple in Chicago. In the last example it was found that the maximum pressure on brickwork, 12 tons per square foot, would be exceeded at the fifth story. Brackets were, therefore, attached to the metal columns placed within the masonry piers, at

[41] *Engineering News*, February 2, 1893.
[42] *Engineering Record*, August 18, 1894.

the fifth and sixteenth floors, to carry the masonry work. The walls were thus only self-sustaining to the brackets of the fifth floor.

The World Building, New York, offers a type peculiar to itself, which may be classified under this head. It consists of two parts, a shell and an interior. The walls are entirely free from the steel columns which carry the weights of the floors, and which stand free from the self-sustaining enclosing walls. In the Cortlandt Street Havemeyer Building, New York, a later structure by the same architect, the walls are immensely thick piers of masonry containing a metal column placed near the inner surface, that carries the floor load.[43]

Veneer walls, in which all the weights are carried on metal columns. This is the typical Chicago system of high building construction, and the list of examples includes a large number of the more important office buildings of that city.[44] Among these may be named the Home Insurance Building, Manhattan, The Fair, Leiter, Y. M. C. A., Isabella, New York Life, Fort Dearborn, Tacoma, Pontiac, Caxton, Venetian, Old Colony, Champlain, Marquette, Stock Exchange, Great Northern Hotel, Ashland, Rand-McNally, Reliance, Title and Trust, Boyce, Hartford, Unity, Security, Columbus Memorial, Teutonic.

[*To be concluded.*]

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[43] *Engineering Record*, November 1, 1890, *seq.*

[44] It should be remarked that very considerable differences in steel construction exist between the practice of New York and Chicago engineers. In the latter city, the unreliability of the soil and the imperative necessity of loading it as lightly as possible, have made its engineers eager to avail themselves of every device which would lighten their loads. New York, on the other hand, has a perfectly stable soil that can be loaded to any extent, and its engineers have, therefore, been much less chary of the use of metal. In Chicago, the natural tendency is to remove every pound of metal that can be spared; in New York, a surplus of metal is often employed. Chicago, therefore, possesses the most typical examples of skeleton and veneered construction.

NOTES AND COMMENTS.*

THE CHICAGO DRAINAGE CANAL.

The report of the Board of Engineers detailed by the Secretary of War to report upon the probable effect and operation of the Chicago Drainage Canal upon the lake and harbor levels, and upon the navigation of the great lakes and their connecting waterways, has been made public. There is nothing to show, the report says, that the consent of Congress has been asked for this enterprise, and it is certain that it has not been treated as an interstate or international affair. With this established fact, it is impossible to think that supervision of the United States will not extend to the canal in due time. This will become necessary as soon as it becomes a part of the system of navigable waterways. If the new outlet reduces the levels of Lakes Michigan and Huron about 6 inches, that effect will be produced in about two years. This is, therefore, not a question of many years, as some suppose. The board feels very sure, therefore, that: (1) the drainage canal is not solely a State affair, but a national one; (2) the tapping of the lakes must affect their levels. If the level of the lakes should be reduced, vessels would have to load accordingly. The trustees of the drainage company now contemplate the abstraction of only 300,000 cubic feet per minute, but after the canal is opened it is assumed that 600,000 cubic feet will be drawn from Lake Michigan. This would lower the level of all the lakes of the system except that of Lake Superior, and reduce the navigable capacities of all harbors and shallows throughout the system. Under the laws of the United States these changes in capacity cannot be made without Federal authority, and, to enable the executive officers of the United States to act advisedly in the matter, it is necessary, in the opinion of the Board, not only that measurements be taken, but also that the money cost of restoring the navigable depths in channels and harbors be carefully estimated. The navigable capacity of all harbors and channels on the Great Lakes below St. Mary's Falls would be injuriously affected by the proposed canal, and the navigability of the inner harbor of Chicago would be made difficult by the introduction of a current therein.—*Scientific American.*

UNSOLVED PROBLEMS IN THE MANUFACTURE OF LIGHT.

Prof. John Cox, in a recent lecture on the above-named theme, before the Royal Society of Canada, presented, in a very striking way, the enormous percentage of loss of energy in all attempts heretofore made to manufacture light through the agency of the steam engine.

To begin with, he points out that in practice not more than from 7 to 16 per cent. of the energy of the fuel used can be realised through the engine, and theoretical considerations establish a limit at about 30 per cent., beyond

* From the Secretary's monthly reports.

which it would seem to be hopeless to expect to pass in any form of heat engine. This he terms one of the unsolved problems.

It is, however, not unsolvable, if we can devise some means of extracting the energy of coal otherwise than by heat—say, in some such manner as that used in burning zinc in a voltaic battery. That this is not beyond the scope of our present scientific knowledge, the recent experiments of Borchers and others bear strong evidence.

In the second stage of the operation of producing the electric light, the dynamo is already so nearly perfect that hardly any heat is lost in its conversion into current.

The third stage brings us to the lamp, with some 7 per cent. of the original energy still available. The only means thus far available for producing luminous energy is to heat the molecules of some substance, and in this operation we are compelled to waste the greater portion of our available energy in producing heat before we obtain the light rays.

"Here, then, is the second unsolved problem, since even in the incandescent lamp and the arc lamp not more than from 3 to 5 per cent. of the energy supplied is converted into light. Thus, of the original store in the coal less than three parts in a thousand ultimately become useful. In the last six years, however, some hint of means to overcome the difficulty has been obtained from the proof by Maxwell and Hertz that light is only an electric radiation. Could we produce electric oscillations of a sufficient rapidity, we might discard the molecules of matter and directly manufacture light without their intervention. To do this we must be able to produce oscillations at the rate of 400,000,000,000 per second. Tesla has produced them in thousands and millions per second, and Crookes has shown how, by means of high vacua, to raise many bodies to brilliant fluorescence at a small expense of energy. * * * These are hints toward a solution of the problem, but give no solution as yet. Prof. Langley states that the Cuban firefly spends the whole of its energy upon the visual rays without wasting any upon heat, and is some four hundred times more efficient as a light producer than the electric arc, and even ten times more efficient than the sun in this respect. Thus, while at present we have no solution of these important problems, we have reason to hope that in the not distant future one may be obtained, and the human inventor may not be put to shame by his humble insect rival."

ACTION OF THE ELECTRIC CURRENT ON FUSED SULPHIDES.

The *Engineering and Mining Journal* gives the following abstract of a paper read by M. Garnier, at one of the recent meetings of the French Academy:

After having determined that carbon, heated to redness under the influence of an electric current of feeble voltage, is transported from the positive to the negative electrode, which fact permitted me to indicate a new method of iron cementation, I thought that this action of an electric current ought not to be limited to carbon. To determine this fact, I made experiments in the laboratories of M. Hillairet. I employed a tube of refractory material

placed horizontally in a reverberatory furnace, and receiving the matter to be electrolysed between the two electrodes in the heated part of the tube. The current was furnished by a Gramme machine. I operated it first on a raw nickel matte from Sudbury, Ontario. I placed a certain quantity of it in the middle of the tube between the two carbons. The spaces between the carbon rods and the walls of the tube were filled with refractory earth mixed with charcoal, to guard against the intrusion of oxygen, but not the exit of gas under feeble pressure, which is formed during the electrolysis, and which can thus escape by the cracks which the heating produces in the clay mass. The matte being melted, I passed a current of ten volts and twenty-three ampères; the current only showed feeble oscillations according to the voltmeters, proving that there was a great regularity in the conductibility of the molten mass. Moreover, the voltage was gradually lowered, although the temperature of the reverberatory furnace was almost constant, which went to prove that the nature of the mixture was changed. After an hour of heating, slow cooling and stoppage of the current, I opened the tube. The positive carbon rod was worn to a feather edge at its upper end, while the negative rod remained intact. Of the matte an analysis was made of those parts which were solidified at the point of contact of the two electrodes. Only the insoluble parts which existed in fragments of the walls of the tube strongly attached to the matte, even after cooling, were eliminated from the samples. Of the analyses given below, No. 1 is of the matte taken; Nos. 2 and 3 are respectively those of the material in contact with the anode and of the cathode after the electrolysis, and No. 4 shows an average of Nos. 2 and 3:

	(1)	(2)	(3)	(4)
S_4	21·10	16·60	4·70	10·65
Fe_4	33·30	35·40	49·10	42·30
Ni_4	16·30	5·13	19·10	12·14
Cu_4	29·00	39·90	26·13	33·02
	99·70	99·90	99·03	98·11

These analyses show that fifty per cent. of the sulphur is eliminated, which sulphur keeps with the copper, especially near the anode; that the iron remains near the cathode, where it seems to accumulate according to the average analysis, No. 4; that the nickel regularly increases in quantity from the anode to the cathode, and the copper diminishes in a regular arithmetical progression from the anode to the cathode. I think that one may conclude from the results of the above experiment that (1) the sulphur combined with the metals in the molten state, in the absence of air when traversed by an electric current (the electrodes, at least the anode, being of carbon), is gradually eliminated in the form of sulphide of carbon; (2) in a mixture of molten metallic sulphides, in the absence of air traversed by an electric current, the electric conductivity of the mixture remains homogeneous at every moment, increasing little by little on account of the gradual elimination of sulphur; the metals and the remaining sulphur arrange themselves in such a way that each elementary section of the bath taken perpendicularly to the direction of the current, has the same electrical conductivity; thus the copper, a better conductor than iron or nickel, keeps the greatest

portion of the sulphur, so that its conductivity may be reduced in the desired proportion.

It is possible, I think, from the above experiments, to explain certain observed phenomena; for example, the mode of distribution of the metals free from, or combined with, sulphur in veins.

UNDER-SURFACE ELECTRIC RAILWAYS.

It has been announced, apparently from authoritative sources, that the results gained by the operation of the Lenox Avenue road, in New York, which has been operated for several months on what is known as the Buda-Pesth underground conduit system, have given great satisfaction. The saving exhibited, it is reported, is 4 cents per car-mile over cable service, and 8 cents per car-mile over horses. In consequence, the Metropolitan Street Railway Company, of New York, under whose direction the above-named experiment was made, has given out the statement that all of the cable and horse railway lines controlled by that company will be equipped for operation by electric power on the under-surface system.

The Electrical World, in discussing the subject editorially, regards the foregoing announcement as highly important, believing that it "may be considered to definitely establish the status of underground conduit working, which will, with scarcely a doubt, soon supersede cable traction throughout the United States, and also lead to a considerable extension of electric traction in our larger cities."

Referring to the Lenox Avenue experiment, it appears that the line has not been subjected to the test of winter weather; the fact, however, that no special trouble from moisture has been experienced at Buda-Pesth, during the five years it has been in operation, is reported to be regarded by the officials of the New York Company as sufficient assurance that no real difficulty will be experienced there from that cause.

The World's editor, indeed, goes so far as to express the belief that the matter is already settled, as witness the following extracts from his comments:

"The question as to trouble from moisture, formerly thought to be inseparable from an open conduit system, has been the crucial one, and is now happily settled. The simplest system of underground conduit electric traction having been demonstrated to be entirely satisfactory, one cannot help but reflect upon the immense waste of ingenuity, and the great expenditure of money and time, on complicated systems devised to obviate difficulties that never had any practical existence."

DEFECTS OF "FIREPROOF" BUILDINGS.

Commenting on the recent disastrous fire at Broadway and Bleecker Street, in New York City, and which involved the destruction of the Manhattan Savings Institution—a modern eight-story iron structure, consisting of an iron frame or skeleton, filled in with masonry—the *Scientific American* points out, and illustrates by sketches, several grave defects of construction, to

which the vulnerability of this building, and presumably of many others may be largely ascribed. One of these is ascribed to the absence of adequate protection of the I-beams of the several floors by fireproof blocks or slabs—which, in this particular case, and doubtless in many others, are carried approximately flush with the base of the I-beams, but do not, as they should, project under and cover them. The lower flange of these beams, it will therefore be seen, has no other protection than that afforded by the ceiling plaster; and the lower half of the main girders has no protection against the heat of a fire. In this particular case, the radical fault of this construction was shown by the fact that, when the fierce flames struck the lower flange of these girders, they stretched and sagged down with their load of I-beams, pulling with them the brick piers upon which their outer ends were borne.

The cheap character of the brick protection also is referred to as another serious fault which contributed to the disaster. In this case, the solid brick arch, instead of springing from the flanges of the I-beams, and being covered to the level of the flooring with sand or ashes, consisted simply of a single layer of thin slabs of brick, with an open air space of 12 inches between this and the wood flooring above.

The conditions necessary to be realised in the ideal fireproof building, according to the writer of the foregoing criticism, are stated in the following terms:

"(1) It should be proof against attack from without.

"(2) The skeleton frame, consisting of steel columns and horizontal girders, should be inclosed in some thoroughly fireproof material.

"(3) It should be able to localise a fire, and confine it to the particular floor upon which it originates.

"In the case of the majority of buildings there is evidence of an attempt at fulfilling the third condition, a partial attempt at the second, and none whatever at the first.

"The first condition can only be met by reducing the window space; building the walls with a facing of the very best firebrick, and furnishing every window with a plate or roller shutter of steel.

"The second condition can be reached by walling in every column and every main girder with high-class firebrick, leaving between the brick and the metal a space that shall be filled in with a preparation of asbestos, similar to that now used on steam piping, or with some similar non-conducting material.

"The third condition can be attained by building firebrick floors with cement finish, abolishing all woodwork, and using metal window casings and sashes, providing each elevator landing with plate steel doors, and, lastly, placing on each floor a powerful water supply. Such a building would be costly, but it would be fireproof." W.

TECHNICAL NOTES.

Among the technical novelties, recently exhibited at the stated meeting, were specimens of *Falconnier's blown glass bricks.* These have been in use

in France and Germany for more than five years, and should not be confounded with the solid blocks of glass formerly used with little success for similar purposes.

Falconnier's blown glass bricks are very light and very strong. They are, in fact, hollow chambers, so shaped as to facilitate their being put together like other building blocks, and are laid so as to present an ornamental appearance. Made in this fashion, the bricks fill successfully the part of double windows with an air chamber incased in a double glass wall, and they are consequently an efficient preservative against cold as well as against heat, and good insulators of dampness and noise. These bricks are hermetically sealed while yet hot, thereby preventing foreign substances or dust from soiling the interior, and they are then annealed to increase their powers of resistance.

The laying of these bricks is plain bricklayers' work, the vaults being constructed over a center of wood, heavy lime mortar, or light cement mixed with fine sand, being used after the whole width of the joint around the brick has been covered with a layer of sizing of a light tint that can be varied according to taste, so as to obtain nice effects of changing colors if desired.

These glass bricks, it is said, are used with good results in the construction of greenhouses and conservatories, as they retain the stored heat for a long time; consequently, a considerable economy of fuel is realised, and also the loss of plants by any sudden or great changes of temperature is averted. They withstand hail and shocks. Sunstrokes which burn delicate plants need not be feared, the surfaces of the bricks being combined so as to diffuse the rays of the sun and obviate the focusing of the solar rays. Certain sizes of these bricks are adapted to the building of conservatories, greenhouses, skylights, awnings, portes-cocheres, etc., and others are especially adapted to the building of walls, partitions for city houses, offices where both light and a partition are wanted, porches, cellar windows, etc.

Vaults, 8 yards in width, and walls 9 yards in height (maximum), can be constructed; vaults and sides of greenhouses, conservatories, partitions, etc., inside of the above measurements, are entirely made of glass bricks without any iron framework; above these dimensions, supports and stanchions are necessary.

A model conservatory erected with Falconnier's blown glass bricks was shown at the World's Columbian Exhibition, and received an award and a very favorable report.

The prize contest between *automobile vehicles*, arranged by the *Chicago Times-Herald*, and which was to have taken place on the 2d of November, was postponed on account of the inability of a number of the contestants to be in readiness for the test. The event was accordingly postponed and took place on November 28th.

Mr. J. De Benneville has succeeded in isolating and identifying several *new carbides of iron*, from specially prepared ternary alloys of iron, chromium and tungsten, and iron, chromium and molybdenum. His observations are regarded as having much importance in iron metallurgy.

BOOK NOTICES.

Aluminium, its History, Occurrence, Properties, Metallurgy and Applications. By Joseph W. Richards, A.C., Ph.D., etc. Third edition, revised and enlarged. Illustrated by forty-four engravings and two diagrams. Philadelphia: Henry Carey Baird & Co. London: Sampson Low, Marston & Co., Ltd. 1896. (Price, $6.)

It is evident, from a comparison of the present edition with its predecessors that the author has kept in close touch with every phase—scientific and industrial—of his subject. The second edition happened to appear most opportunely. The electric methods for the reduction of aluminium had just fairly begun to demonstrate their immense superiority over the chemical processes, which they have since completely supplanted; there was a widespread public interest in all that pertained to the then new metal, concerning which the most extravagant notions were entertained, and the most exaggerated claims were made. Of the book, it is not too much to say that its immediate and remarkable success, while in some measure ascribable to the peculiar circumstances above referred to, was, in much greater measure, due to the thoroughness and accuracy of the author's work. Not a single phase of the subject escaped his attention, and it has won for its author respect and admiration. There are few technical works of American origin which may compare with it, and none which excel it, in the conscientious work which has been bestowed upon it.

The present edition follows the same lines in treating the subject as its predecessor, and brings it up to date. Several of the chapters, notably the historical introduction, the discussion of the fundamental thermo-chemical considerations involved in the understanding of the electrical methods of reduction, the results of the electrical methods, and the important branch of the alloys of aluminium, have been largely revised or re-written. Taking the work as a whole, it is worthy of the highest praise.

The publisher, also, is entitled to mention for having issued it in a highly creditable manner. W.

The Electric Transmission of Energy. A Manual for the Design of Electrical Circuits. By A. V. Abbott, C.E., Chief Engineer Chicago Telephone Company. 586 pp., with nine folding plates. D. Van Nostrand Company, and Sampson Low, Marston & Co. $4.50.

In the preface the author modestly disclaims anything "strange or remarkable in the present volume," yet the book is a valuable addition to electrical literature. It is decidedly up to date. For instance, it contains drawings of the Lenox Avenue conduit in New York, and of the Love conduit in Washington, upon whose successful operation during this winter, perhaps, depends the future form of electric railway transmission in the large cities of the United States.

The drawings are clear, and the pictures of line appurtenances especially good. The reader is refreshed by the absence of a tiresome explanation of

the principles of the dynamo, and is grateful to feel that at last he can be presumed to know something of electrical induction as well as of the multiplication table.

After discussing the line, measuring instruments, and methods of measurement, the question of the designing of electric circuits, as would be expected from the title, is given an extended treatment. The writer has brought together materials from numerous sources, and put them in such accessible shape as to deserve the gratitude of the designer. The seventy-eight tables and nine plates will be especially appreciated.

Regard has been had to both American and European practice. Why, among the notable instances of polyphase transmission, does the system Buelach-Oerlikon not appear? Both Sartori, in his "Trasmissione Elettrica," and S. P. Thompson, in his recent book, cite it, and with reason; for 13,000 volts between adjacent wires is a trifle unusual. Of American plants, those at Pomona, Redlands, Portland, Telluride, Concord and Niagara are described.

The value of the treatment of line design would have been much enhanced had the author proposed a definite problem of transmission, and then worked it out in every detail, thus illustrating the application of his formulæ and tables.

The subject of each section is printed in heavy type—a commendable feature. After the text follows an exhaustive index of seventeen pages.

Whenever the author leaves the distinctly practical side of his subject he is not so fortunate. One has the feeling that he is not very sure of his ground. The definitions of the volt and the coulomb, p. 223, the derivation of the coefficient of self-induction of a circular current, p. 317, entirely without regard to the area of the circle, the absence of the familiar sine of one-half the angle of deflection law in the discussion of the ballistic galvanometer, will serve as illustrative points. This criticism, however, does not affect the value of the book as a whole, but only the value of a minor part, of a part, indeed, that need not have appeared in a book bearing the title above given.

G. F. S.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, December 18, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, December 18, 1895.

JOS. M. WILSON, President, in the chair.

Present, 90 members and 14 visitors.

Additions to membership since last report, 16.

The resignation of Mr. J. C. Trautwine, Jr., from the Board of Managers was presented and accepted. Mr. C. Hartman Kuhn was elected to serve for the unexpired term.

The following nominations were made for officers, managers and committee men.

For *President* (to serve one year), . . . JOSEPH M. WILSON.
" *Vice-President* (" three years), . . . CHAS. BULLOCK.
" *Secretary* (to serve one year), . . . WM. H. WAHL.
" *Treasurer* (" " "), . . . SAMUEL SARTAIN.
" *Auditor* (" three years), . . . SAMUEL H. NEEDLES.

For *Managers* (to serve three years).

WASHINGTON JONES,
THEO. D. RAND,
ISAAC NORRIS,
CHARLES H. BANES,
STACY REEVES,
F. LYNWOOD GARRISON,
THOS. P. CONARD,
COLEMAN SELLERS,
HENRY GAWTHROP,
W. L. BOSWELL,
JAS. M. DODGE,
JOHN G. BAKER.

For members of the *Committee on Science and the Arts* (to serve three years).

ARTHUR BEARDSLEY,
HUGO BILGRAM,
FRANK P. BROWN,
JOHN H. COOPER,
N. H. EDGERTON,
G. M. ELDRIDGE,
F. L. GARRISON,
REUBEN HAINES,
W. N. JENNINGS,
ARTHUR KITSON,
C. J. REED.
EDWARD F. MOODY,
E. ALEX. SCOTT,
COLEMAN SELLERS,
H. W. SPANGLER,
WM. H. WAHL,

Mr. Pedro G. Salom read a paper on Automobile Vehicles, with incidental reference to the recent prize contest arranged by the publishers of the Chicago *Times-Herald*. Mr. Salom illustrated his paper by the exhibition of a number of lantern pictures of various types of such vehicles, of American and foreign design, and by the exhibition of the Morris-Salom "Electrobat," No. 2, an electrically propelled vehicle, which was awarded the first prize, a gold medal, in the prize contest above referred to. The meeting voted to refer the Morris-Salom vehicle to the Committee on Science and the Arts for investigation and report. Mr. Salom's paper, with the discussion thereon, will appear in the *Journal*.

Mr. C. Francis Jenkins, of Washington, read a paper giving an account of the development of the art of reproducing, by photography and optical accessories, the movements and actions of living subjects, and illustrated the subject by means of the phantoscope, a projecting apparatus devised by him for this purpose. With this instrument Mr. Jenkins succeeded in reproducing, in life size, on the screen, the movements and actions of dancers, gymnasts, etc., with remarkable fidelity to nature.

On account of the lateness of the hour, a communication from Dr. Grimshaw and the report of the Secretary were omitted.

Adjourned.

WM. H. WAHL, *Secretary*.